ИЗВЕСТИЯ
АКАДЕМИИ НАУК СССР
СЕРИЯ ГЕОЛОГИЧЕСКАЯ

PUBLISHED IN TRANSLATION BEGINNING WITH THE 1958 RUSSIAN VOLUME YEAR.

IZVESTIYA AKAD. NAUK SSSR

SERIYA GEOLOGICHESKAYA

1961 | No. 6, June

CONTENTS

TWENTY-SIXTH YEAR OF PUBLICATION

Technical Editor - V. Ya. Karasev

T-05294. Approved for printing May 18, 1961.
Circulation - 3, 275 copies. Order 3775
Paper size 70 x 108-1/16 Paper 4 Printing sheets 10. 96 Publ. sheets 12. 6

Second printing office of the USSR Academy of Sciences Publishing House.
Moscow, Shubinskiy per. 10.

LOOKING TOWARD THE TWENTY-SECOND CONGRESS OF THE COMMUNIST PARTY OF THE SOVIET UNION[1]

The economy of our country and Soviet sci-:e have scored a great success. Because of achievements of Soviet science and technol-' and because of characteristics of his own, 'iet Major Yu. A. Gagarin has opened up a v era in the history of mankind, the era of n's penetration into the cosmos. The de-opment of all branches of the U. S. S. R. econ-y is rapid, and a new image of Soviet Man ses, with his tendency for creative work and the building of a bright future for commu-t society.

After an analysis of party activity in the first rs of the current Seven Year Plan, the enty-Second Congress of the C. P. S. U. will iew the path travelled by the first socialist ntry and, what is more important, will chart further progress toward the highest phase of ialism, true communism. Of particular im-tance in this respect is the development of ence and technology, communist education of toilers, and the elimination of assorted prej-ces inherited from the old world.

"No society is in greater need of science than ommunist society. Without a profound knowl-e of physics, chemistry, mathematics, bi-gy, and other natural sciences, it is im-sible to create the mighty productive forces able of bringing about the abundance of mate-l goods without which there is no commu-m." ("Kommunist," No. 3, 1961, p. 8).

This high esteem for science in the Soviet te is manifested in the constant concern of the ty for the development of science in this ntry. Especially significant in this respect he Resolution of the Central Committee of the ?. S. U. and the Council of Ministers of the 5. S. R., of April 1961, on "Measures For A ter Coordination of Scientific Research and Activity of the U. S. S. R. Academy of Sci-es." While noting the great achievements of iet science, this resolution points out the serious shortcomings in its organization in general, and those in the Academy's activity, in particular.

The Central Committee of the C. P. S. U. and the Council of Ministers believe that under prevailing conditions a further strengthening of theoretical study is most important in those fields which bear on the overall economy of the country. This resolution clearly defines the activity of the U. S. S. R. Academy of Sciences: "The Academy should exercise scientific and methodologic leadership in research in natural sciences (physics, mathematics, biology, and sciences of the cosmos and the earth, as well as in the humanities, and apply the results to the development of social economy and culture."

Another important task is assistance to other scientific research institutions of the country in their theoretical problems, a development of communication with scientific institutions of other countries, and training of scientific personnel.

On the eve of the Twenty-Second Congress of the C. P. S. U., and fully instructed as to the direction of their efforts, Soviet scientists should review thoroughly their projects, the distribution of scientific effort, the organization and equipment of their scientific institutions in order to cope with momentous tasks which the exigency of life poses before them.

Our scientific institutions still lack the necessary concentration of means and effort on the most vital problems. There are minor projects not organically related to compound problems worked on in various institutions. It often happens that specialized problems take up long years without bringing substantial and timely theoretical results.

The main field of basic research for theoretical geologists is of course the earth's crust with its resources. It is naturally broken up into several important fields of study: the crust, its composition, structure, and regularities in the distribution of its resources. In the solution of individual problems in these fields, there is a

[1]Navstrechu XXII s"yezdu kommunisticheskoy 'tii sovetskogo soyuza. pp. 3-4.

proper place for all geologic disciplines, without regard to the present high departmentalization according to administrative affiliation.

Those working in the field of petrography, mineralogy, geochemistry, stratigraphy, and tectonics, should review their main projects in the light of this momentous overall problem. Even such specialized studies as volcanism and the geology of ground water (including deep thermal waters), cannot be excluded from the overall plan of study.

The study of the crust should be carried on in a diversified and comprehensive way. It should be based on the achievements made by the geologic sciences themselves, with their peculiar historical approach to natural phenomena; as well as on the discoveries of modern physics and chemistry, the application of isotopes and of geophysical and crystallochemical methods, and on the knowledge of the physical and chemical properties of the crust. Only the concerted action of the numerous groups of scientists involved in the solution of the problems of the crust may lead to our goal, a knowledge of the earth on which we live, and the bringing of its resources of mineral raw material and power to the service of a communist society.

In the light of the new problems confronting the scientific institutions of the Academy, experimental studies are of particular importance as are those in radiogeology and in the physical properties of rocks and minerals.

The problem of the upper mantle, formulated by the International Geophysical Union, is closely related to the basic field of geology, a study of the crust. Such interrelated problems can be solved only by close cooperation among theoretical geologists, geophysicists, and industrial geologists. The role of industrial geologist is particularly important in the designing and application of complex specialized equipment for deep drilling (10 km and better) at high pressures and possibly high temperatures (300 to 400° C) on the continents and perhaps in the ocean bottom.

A solution of all these problems is possible only with a concerted effort of a number of scientific and industrial organizations.

METASOMATIC PHOSPHATE DEPOSITS IN LOWER PERMIAN DEPOSITS OF THE URALS[1]

by

I. V. Khvorova

In studying the Lower Permian marine mo-sse of the southern Urals, this author noticed, the Assel stage, some peculiar rocks ap-eciably more porous and cavernous than the rrounding limestones, and differing from them color. It appeared at first glance as though y were the same limestones but strongly al-ed by eluvial processes; further observations ve shown, however, that standard weathering uld not have formed such rocks.

It turned out that we deal here with high-ade phosphate deposits of an unusual meta-matic origin. They have been observed in the htyubinsk Oblast', on the right bank of the aksa-Kargala, northeast of the Dombar ver mouth, in what is called by geologists the mbar Highlands. Accordingly we shall call se phosphate deposits, and the place of their currence, the Dombar (Figure 1).

UTLINE OF THE GEOLOGY OF THE AREA

Tectonics. The Dombar area is located in upper Paleozoic folded zone, on the western pe of the southern Urals, and at the eastern ındary of that zone. Best developed here are wer Permian Assel rocks, with a steep west-y dip (S — 70° — W; at 75 to 90°); near the mbar River, they are replaced by young-Sakmarian beds. The homoclinal Lower rmian rocks are associated with the eastern ıb of a syncline whose middle is filled up with tinskian rocks which crop out outside the area question.

In the east, the Lower Permian rests uncon-mably and transgressively on Viséan rocks posed in a broken band. Viséan beds, unlike Lower Permian, dip to the east, steeply °) to relatively gently (30 to 40°). Thrust r them from the east is the Zalair formation; the middle part of the Dombar area, the Zalair formation completely overruns the Viséan and rests directly on the Assel (Figure 1).

Stratigraphy. We are interested here only in the Assel deposits with which the phosphate deposits are associated. These deposits rest unconformably on blue to green tabular, siliceous Viséan rocks and are overlain conformably by terrigenous Sakmarian deposits.

The following four members are differentiated in the Assel stage of the Dombar area (reading upward):

1. Light colored thick-bedded, detrital organic limestones, brownish dolomites and dolomitic limestones with an addition, locally abundant, of polymictic sand and gravel; locally with boulders and small chunks of Carboniferous bioherm and stratified limestones. There is an abundance of small fragments of siliceous Viséan rocks. Thickness, 175 m.

2. Boulder and block limestone conglomerate, interbedded with sandy, pebbly layers and layers almost free of terrigenous matter, organic detrital limestones, locally dolomitic. The conglomerate consists of boulders and small blocks (up to 2 m in diameter) of assorted limestones, white to gray, of a bioherm origin, free of terrigenous material, as well as organic detrital beds, with sand and gravel. The boulders and blocks locally form large, solid, irregular lenses which rapidly change laterally to clastic and organic detrital limestones with isolated blocks. The phosphate beds are associated with one such lens at the base of the sequence. Total thickness, 300 m.

3. Arenaceous-argillaceous sequence with beds and horizons of calcareous gravel and conglomerate, 300 m thick.

4. Sandy, pebbly conglomeratic sequence of polymictic composition, 385 m thick.

The overall thickness of the Assel stage is about 1200 m.

Lateral changes. The thickness and the

[1]Metasomaticheskiye fosfority sredi Nizhneperm-kh otlozheniy Urala. pp. 5-17.

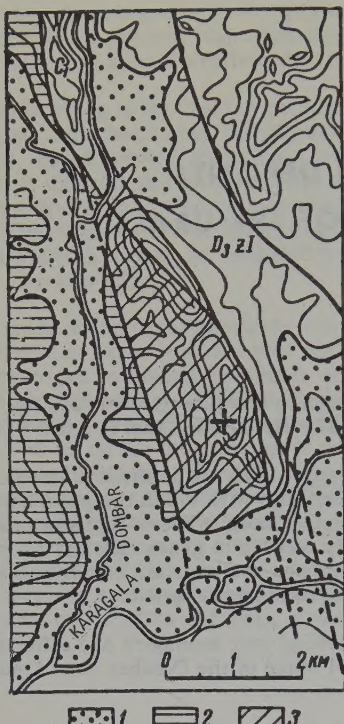


FIGURE 1. Generalized geologic map of the Dombar area.

1 - Quaternary alluvium; 2 - Sakmarian; 3 - Assel; C_1 - Lower Carboniferous; $D_3{}^{zi}$ - Zalair formation; + - phosphorite deposit.

stratigraphic composition of this section vary substantially over short distances, meridionally. Just north of the Dombar area, the Assel deposits are missing and the Lower Carboniferous is overlain unconformably by Sakmarian terrigenous deposits. The same situation prevails to the north, for approximately 23 km, as far as Kiya River; at its right ank, the Assel deposits reappear, now accompanied by thick Upper and Middle Carboniferous sections. On the left bank of the Zhaksa-Kargala, south of the Dombar area, the Assel section is the same as in Dombar, but its thickness is reduced to 600 m because of a wedging out of its first member and of most of the second. Unlike the Dombar area, the Assel here is unconformably on Lower Namurian limestones, with large blocks of white and pure organic Moscovian limestone locally preserved above them, as well as occasional thin Upper Carboniferous organic detrital pebbly limestones. This section is traceable for 25 to 27 km, and the entire Assel section is present only farther south where it is conformably on thick Upper Carboniferous flysch.

Only 7 km west of Dombar, the coarsely clastic high-carbonate Assel rocks with their numerous blocky beds are replaced by regularly stratified sandstones and shales with rare conglomerate beds. Here, the Assel deposits rest conformably on thick Upper Carboniferous flysch.

Thus, the Dombar area is located in the least complete zone of the upper Paleozoic, with the Upper and locally the Lower Namurian missing, as well as the Middle and Upper Carboniferous, and the Assel missing north of Dombar. In the north, south, and west, this zone is bound by areas of very thick Upper Carboniferous flysch, with another thick Lower Permian section conformably above them.

Structure of the area. The rapid changes of the Assel section and its relations to older sections are determined by certain features of the eastern fringe of the south Uralian trough.

The so-called Kiya uplift protruded into the trough from the east, in the Middle and Late Carboniferous. Only its extreme western tip is accessible for study. The incomplete section mentioned above is associated with this uplift. An analysis of Carboniferous facies and thicknesses suggests that the uplift was of a horst type, probably related in some way to the central Uralian zone. Morphologically, this structure was a cordillera bound on the west, north, and southwest by considerable depths where flysch was deposited. This cordillera was submerged, now and then, and thin shallow-water carbonate beds were deposited over it; at other times it stood high and underwent erosion. At the onset of the Permian, the Kiya uplift was involved in a differential subsidence, evidently associated with its breaking up into individual blocks.

The Dombar area represents one such block; it began to subside before its neighbor to the south and especially to the north. This is why the entire Assel section is present here, while it is missing in the north and only partly present in the south, on the right bank of the Zhaksa-Kargala.

Paleogeography. At the beginning of Assel time, the Dombar area was located in the littoral zone of a marine basin, with its shore broken into locally steep cliffs, of Carboniferous limestones, including numerous bioherm varieties. Accumulated offshore were shallow-water, mostly carbonate, clastic, and organic sediments, with occasional piling-up of blocks falling from the cliffs, probably due to earthquakes; individual blocks are 5 to 7 m across. The absence of fine grained deposits, coupled with well-rounded clastic and shell material, indicates shallow and mobile water.

PETROGRAPHY OF PHOSPHATE BEDS AND ENCLOSING ROCKS

Dominant among the Donbar phosphate de-
sits are boulder- to blocky varieties, with
er conglomerates also present. The blocks
l boulders usually are light-colored, with
tish to yellowish, less commonly pink, hues.
ese rocks show a bizarre pattern of caverns
l spots, with numerous incrustations, and
ally resemble bioherm limestones. Blocks
h a breccia structure are fairly common.
e finer conglomeratic varieties (Figure 2) are formed by fragments from fractions of a centimeter to several centimeters long, cemented by a small amount of fine-grained material. This rock is brown-gray to mottled, because of the red, pink, and gray pebbles; it is locally cavernous, with the cavern walls always covered by a white crust. Unlike the boulders and blocks which are free of terrigenous material, the fine-pebble phosphates carry small fragments of vein quartz and metamorphic schists.

FIGURE 2. Fine-pebble phosphoritic conglomerate with isolated pebbles of quartz (a) and siliceous rocks (black).

Microscopic study has shown that these rocks consist of two varieties of phosphate: finely dispersed, sometimes called "amorphous"; and obviously crystalline. The first, as seen in passing light, is a dense yellowish groundmass more or less colored by iron hydroxide; it either does not show any birefringence, or else responds weakly to polarized light, as the result of a partial and very fine crystallization; its refractive index is 1.603. The second variety is formed by transparent elongated prismatic hexagonal to acicular crystals, uniaxial, optically negative, with a negative elongation and $\omega = 1.616$ and $\epsilon = 1.610$. Judging from the refractive indices, this is francolite. The crystal size is different for different segments, from quite small (0.005 x 0.015 mm) to 0.015 x 0.3 mm.

The structural features of phosphate beds are particularly conspicuous in thin section, seen in passing light. Their organic or clastic texture is generally quite obvious (Figures 3 and 4). The fragments (pebbles) are clot-like. oölitic, organic detrital, mudstone, or fine-grained, depending on the limestone of their origin. Their structural similarity is enhanced by the presence in some phosphates of numerous rhombohedrons reminiscent of dolomitic types

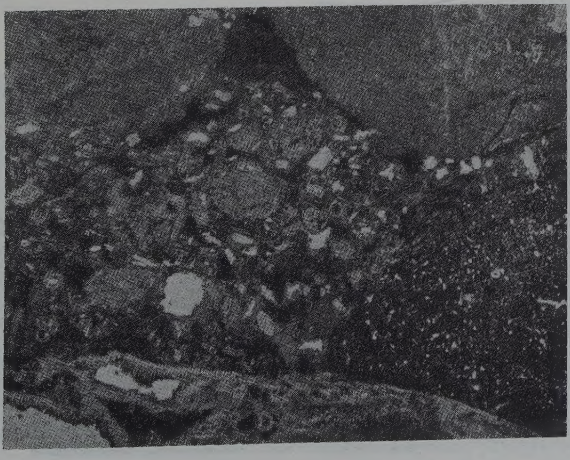


FIGURE 3. Fine-pebble phosphoritic conglomerate.

On the right, a pebble of phosphatic sponge-spicule rock. Single nicol; 8X.

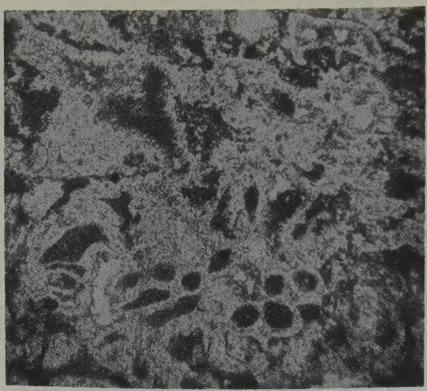


FIGURE 4. Phosphorite with relicts of organic texture (phosphatic organic detrital limestone).

Single nicol; 33X.

(Figure 5) and made up of fine-grained francolite. In addition to these fragments of what obviously were carbonate rocks, there are pebbles of rocks consisting of sponge spicules and radiolaria, and of metamorphic and extrusive rocks. Most of the fragments have been replaced by phosphate, with only a few having preserved the original composition or having been partially replaced. All of the limestone fragments and shells have been phosphatized, as well as their binding groundmass, with some fragments consisting of "amorphous" phosphate, the other, crystalline, and still others of both. This is determined to a certain extent by the primary structure of carbonates: "amorphous" phosphate is associated with homogeneous fine-grained segments, while the crystalline replaces the rhombohedrons, shells, and the relatively coarse-grained portion of cement; at the same time, the crystalline francolite is developed irrespective of the sedimentary structure, by forming intricate veinlets and inclusions in the amorphous body, in places completely replacing the fragments and shells whose outlines are preserved in the fine residual envelope of "amorphous" phosphate. As we shall see later on, similar relations between pelitomorphic and finely crystalline calcite, associated with epigenetic recrystallization, have been observed in the limestones, as well. The structural heterogeneity is particularly strong in massive cavernous phosphates which form numerous boulders; the distribution of the "amorphous" and crystalline components here is quite similar to that of variously recrystallized segments in bioherm limestones (Figures 6 and 7).

Crustification is quite common and conspicuous in phosphates. Fine crusts (0. 2 to 0. 5 mm thick) of prismatic to acicular francolite crystals cover the fragments and shells, the cavern walls, and often originate independently of the primary texture. The incrusted cavities are commonly filled up with iron hydroxide (Figure 8), coarse quartz crystals (Figure 9), and pelitomorphic calcite (Figure 10). The latter was obviously formed after the phosphatization, and its presence in the caverns warrants special mention.

The phosphates contain a comparatively small amount of noncarbonate fragments maintaining their original composition. Thus, one of the

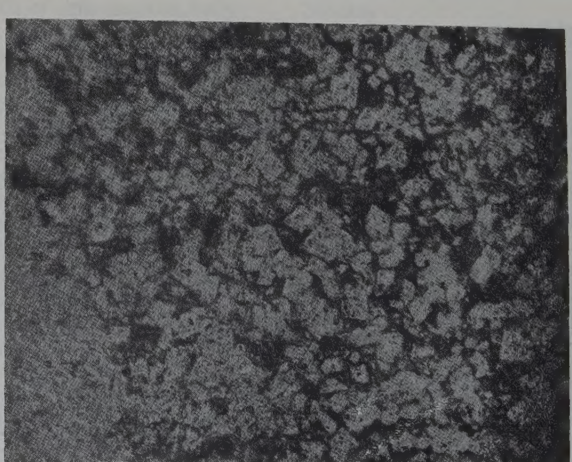


FIGURE 5. Phosphorite with relicts of dolomitic rhombohedrons (phosphatic dolomite).

Single nicol; 86.5X.

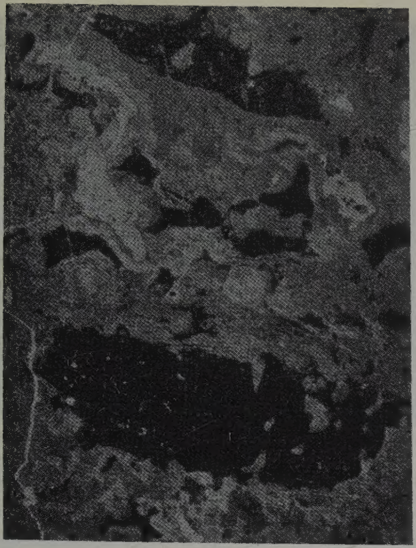


FIGURE 6. Mottled phosphate; dark "amorphous" francolite; and light crystalline francolite.

Single nicol, 7.5X.

FIGURE 7. Typical "mottled" structure of bioherm limestone.

Single nicol; 5.5X.

n sections shows a pebble with a groundmass irregularly arranged small prismatic crys- s of francolite and a few idiomorphic in- istation of quartz, reminiscent of pheno- ysts in porphyries or quartz keratophyres gure 11). Obviously, this is the phosphatized ble of an acid extrusive rock. Also present small fragments of spilites, partly-to-fully laced by francolite. The latter is developed relatively large crystals on plagioclase leists parated by cryptocrystalline phosphate with served products of greenstone alteration, thy epidote and leucoxene.

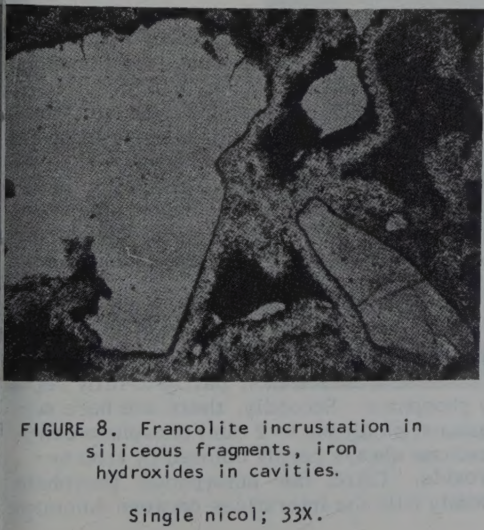


FIGURE 8. Francolite incrustation in siliceous fragments, iron hydroxides in cavities.

Single nicol; 33X.

Incomplete replacement by phosphate has been observed in some sponge spicule and radiolarian rocks, where the groundmass is represented by "amorphous" phosphate while the organic remains have preserved their chalcedonic composition. Interesting partial phosphatization has been observed in a fragment of garnetiferous micaceous quartzite: several thin "partings" with abundant finely crystalline phosphate carrying only extremely fine lenticular quartzite bodies, strongly decomposed biotite scales, and isolated grains of garnet. In the intermediate "partings" phosphate is present only in dendritic veins and quite small isolated inclusions (Figure 12).

Many phosphorite samples carry small additions of sand, both in cement and in the pebbles. The sand grains are quartz; feldspars, quite common in contemporaneous limestones, are missing here. Instead there are phosphate grains, of the same size and shape as the quartz, and unlike the limestone fragments; these obviously are feldspars replaced by francolite.

The chemical composition of the phosphates is illustrated in the table. It shows the broad range of the insoluble residue content (2. 5 to 23%) determined by variation in the terrigenous material content, abundant in sandy and pebbly varieties, and insignificant in bioherm rocks (analyses 1, 3, 9). The low CO_2 content suggests the fullness of phosphatic metasomatism.

As pointed out before, phosphates are developed in limestone interbedded with dolomite.

FIGURE 9. A cavern in phosphorite, filled up by quartz with incrustations of prismatic crystals of francolite.

Nicols crossed; 33X.

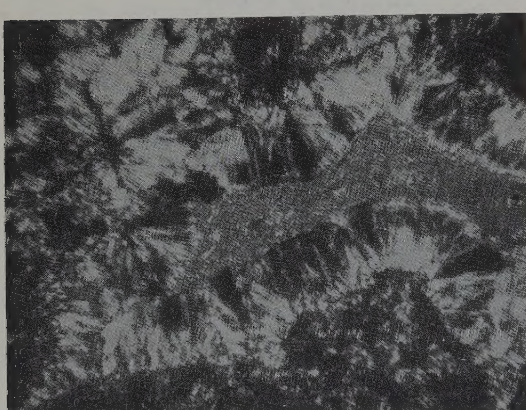


FIGURE 10. A cavern in phosphate, filled up with fine-grained calcite with francolite crystals.

Single nicol; 33X.

The limestone is clastic, organic, or less commonly amorphous. The first variety is represented by fine pebbles of fine-grained, foraminiferal, coagulated, oölitic, and other limestone; i. e., those occurring in the phosphates. The second variety is diversified in composition, size, and degree of rounding of its fragments. All these rocks are unevenly but fairly strongly recrystallized, especially the coarsely detrital varieties. Relatively coarse calcite crystals are developed mostly in the groundmass, although the recrystallization often affects the fragments, as well, in which case only a thin crust of microcrystalline calcite remains. Recrystallization proceeds without regard to the sedimentary structure, in veins and intricate patterns of fine- to medium-crystalline calcite. Relationship between the fine and coarser grained components, in limestones, is reminiscent of that between the crystalline and "amorphous" component of the phosphates, being somewhat more complex in the phosphates.

Often present in the limestones are polymictic sands and gravels, with the grain composition, form, and size, the same as in the phosphates, except that the phosphate beds alone contain feldspar grains, as well as somewhat more numerous fragments of cryptocrystalline argillaceous and siliceous rocks. Characteristically, many fragments have been strongly corroded, with an internal development of calcite; in places they are cut by calcite veins. Veinlets and partings of secondary quartz have been observed in a fragment of micaceous quartzite. All these products of redistribution of calcium carbonate during epigenesis are quite similar to the corresponding phosphate formations.

Microscopically, there is practically no evidence of phosphates in the limestones. Out of the numerous thin sections inspected, a single one showed a few small (up to 2 mm) diagenetic phosphate grains. Another section contained a rounded fragment of radiolarian rock, partly phosphatic.

Carbonate analysis of limestones shows a considerable variation in the insoluble residue content (6 to 15%) in addition to a generally small, magnesium carbonate content (0 to 2. 5%, seldom 7%). The amount of P_2O_5 in the limestones is usually on a par with the Clarke index, rarely approaching 1%.

Structurally, the dolomites are quite uniform, usually being a product of limestone dolomitization. They are irregularly granular: in one thin section, the rhombohedrons range from 0. 02 to 0. 2 mm. The rock usually shows a clastic to organic structure, with some shells keeping their calcite composition. The terrigenous fraction is the same as in the limestones. Unlike the limestones, the dolomites are considerably more porous and slightly colored with iron hydroxide which occasionally forms small nodules.

The presence of phosphates in the dolomites is more conspicuous. First, they, like the limestones, carry very fine fragments of fine-grained siliceous rocks, partly-to-fully replaced by phosphate. Secondly, there are here occasional small (up to 2 mm) phosphate concretions always deeply colored by iron hydroxide. Third, the "amorphous" phosphate locally fills the interstices between dolomitic

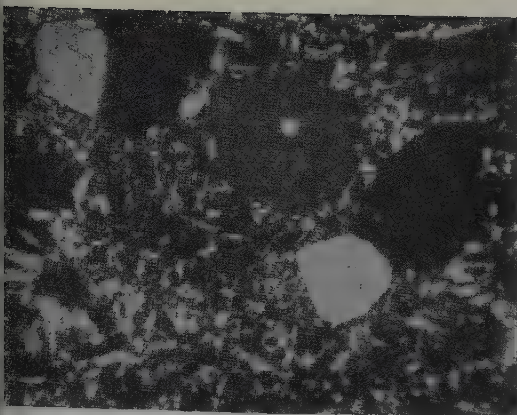


FIGURE 11. Phosphatic extrusive rock with quartz phenocrysts.

Nicols crossed; 81X.

rhombohedrons or forms dendritic veinlets; also present are veinlets of cryptocrystalline chalcedony with numerous extremely fine (< 0.003 mm) phosphate grains. There are occasional secretions of phosphate with or without silica on the pore walls; the pores could have been filled up with a soft phosphatic substance which was leached in weathering. It should be noted that the qualitative field analysis of samples for phosphorous has always colored the wall pores intensively.

Carbonate analysis of the dolomites has revealed a high content of insoluble residue (11 to 20%) and of $MgCO_3$ (25 to 30%), with a small P_2O_5 content (0.15 to 0.75%). No appreciable relationship has been observed between the amount of phosphorus and the degree of dolomitization; it is practically the same in both limestones and dolomites. The certain conflict between the chemical and microscopic data is evidently due to the higher dispersion of phosphate compounds in the limestones, which renders them less conspicuous.

Petrographic studies of carbonate rocks and the phosphates lead to the following conclusions:

1. The Dombar phosphates are of metasomatic origin, having been formed by francolite developed on already lithified carbonate rocks, by completely replacing calcite and dolomite, and partly the terrigenous material as well, such as feldspars and acid and basic extrusives. The quartz and micas (muscovite, biotite) remained unreplaced, with the phosphate veinlets in quartzites and metashales having originated in the replacement of corresponding calcite formations.

2. Phosphatization took place after dolomitization and silicification.

3. The nature of phosphatization is determined to a certain extent by the structure of the carbonate rocks. At the same time, the crustification phenomena are typical of the phosphate beds only; it appears that locally francolite grew on the walls of hollow caverns, with some of them subsequently filled up with fine-grained quartzite.

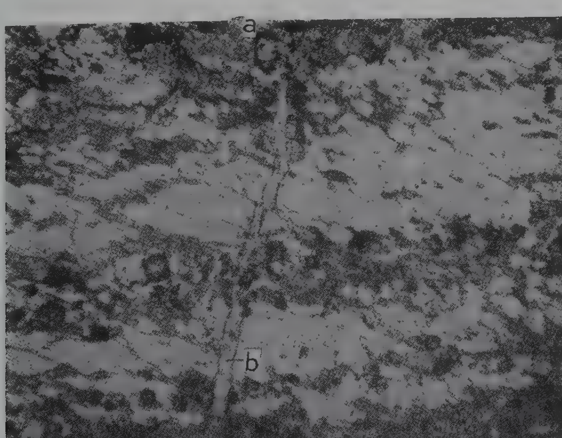


FIGURE 12. Micaceous quartz with "partings" (a) and veinlets (b) of phosphate.

Single nicol; 36X.

Chemical composition of phosphates

Anal. Nos.	Sample Nos.	Appearance of phosphates	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	FeO	P_2O_5	CaO	MgO	K_2O	Na_2O	H_2O+	H_2O-	CO_2	C	F
1	641[a]	Light-colored, porous	0.80	1.56	None	0.42	0.12	35.27	52.80	0.61	0.04	0.51	1.99	0.29	4.20	0.34	—
2	641[b]	Finely clastic	12.44	1.38	"	0.03	0.27	32.37	46.20	0.83	0.20	0.23	1.85	0.39	3.26	0.35	—
3	641[c]	Pink, breccia-like	2.70	2.76	"	1.14	0.14	34.94	50.45	0.30	None	0.27	1.84	0.32	3.54	0.4	—
4	641[d]	Composite of several hand specimens	11.80	1.37	Trace	0.67	0.14	32.44	46.20	0.46	0.20	0.31	1.56	0.44	3.08	0.42	—
5	641—1	Gray, finely clastic	7.75	0.86	—	1.70	—	32.08	48.05	1.05	—	—	—	—	4.04	—	3.09
6	641—2	" "	7.51	1.45	—	2.76	—	32.95	47.45	0.72	—	—	—	—	4.21	—	2.75
7	641—3	" "	21.42	0.45	—	1.34	—	27.61	42.04	0.45	—	—	—	—	3.66	—	2.65
8	641—4	Sandied	7.29	0.96	—	1.86	—	33.45	49.54	1.08	—	—	—	—	2.10	—	3.09
9	641—5	Pink, breccia-like	2.79	0.58	—	1.92	—	35.58	52.35	0.90	—	—	—	—	3.20	—	4.22

[1]Samples 1–4 were analyzed in the Chemical Laboratory of the Geological Institute of the Academy of Sciences of the USSR, samples 5–9 — in the Analytic Laboratory of the Mineral-Chemical Research Institute.

4. The phosphatization was accompanied by a weak "ferruginization" and silicification of rocks, with the silica precipitated together with phosphate (thin growths of cryptocrystalline chalcedony in "amorphous" phosphate), or somewhat later on (as a pore filling).

THE FORM OF THE ORE BODY

In plan, the Dombar phosphate deposits form an asymmetric lens, about 90 m long, with a maximum thickness of about 40 m, on the whole conformable with the enclosing rocks; in the south, it trends N — 10° — W; in the north, N — 40° — W. Its northern end is blunt; the southern sharp (Figure 13). Its dimensions and form cannot be accurately determined, even in plan, without mining works. Neither do we have any data on its plunge.

Only phosphates are developed within the lens; no unreplaced limestones have been observed, at least in the exposure. The lens outlines are sharp, with non-phosphatic rocks developed immediately outside. Four samples were taken near its southern end, fairly well exposed, as close as possible to the ore body, not farther than 0.5 to 1.0 m from the pure phosphate outcrop. The content of P_2O_5 in these samples was 0.04, 0.17, 0.01, and 0.55% (Figure 13), with 0.99% some 50 m away from the southern wedge-out of the lens. This is the P_2O_5 content for the Dombar Assel carbonate rocks; consequently, there is no phosphate enrichment of limestones in the vicinity of this phosphate body.

As shown in the cross-section (Figure 13), the phosphate deposit is associated with a boulder bed lens. However, the deposit does not follow the lens outline. A finely clastic limestone above the main boulder bed touches the phosphate body in the south and either is part of it or else wedges out on its side. Unfortunately, it was impossible to ascertain which was the case.

In order to determine the distribution of phosphorus in limestones enclosing the phosphate body, we sampled, layer by layer, the interval stratigraphically below it and somewhat to the north, also a small lentil immediately underlying it (Figure 13). The testing was done with a nitric acid solution of ammonium molybdenate; in addition, 20 samples were taken for control chemical analyses.

Qualitative testing and chemical analyses have shown the absence of any appreciably phosphorous enrichment. Nowhere did the P_2O_5 content exceed 1.5%; usually it was about 0.1%; certain stratigraphic horizons show some small enrichment (0.75 to 1.05%), subject to strong fluctuations and occasionally dropping to the Clarke index; this last circumstance is evidently

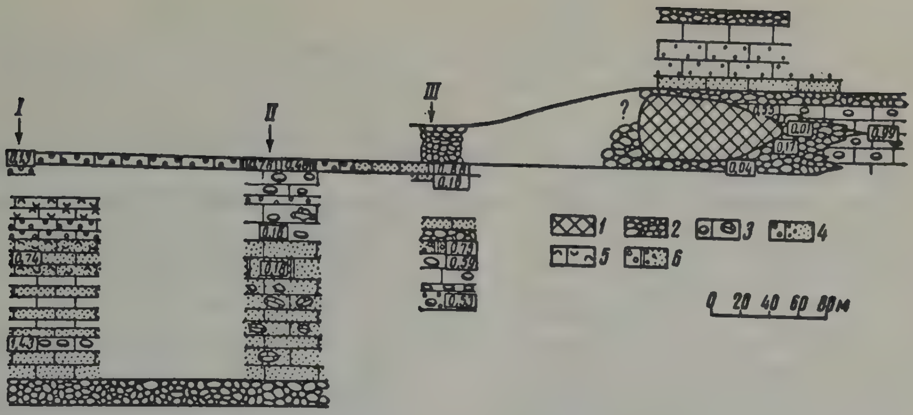


FIGURE 13. Diagrammatic cross-section of Assel deposits with a phosphate lens.

1 - phosphate beds; 2 - boulder-block limestone conglomerate; 3 - limestone with occasional chunks; 4 - sandy and gravelly limestone; 5 - organic detrital limestones; 6 - dolomites; Roman numerals - exposure numbers; figures in boxes - % content of P_2O_5 in rock.

explained by a diagenetic redistribution of phosphorus in the sediments. In rocks on the level with the phosphate lens and above, the phosphorus content was either normal or only slightly higher (about 1% P_2O_5).

ORIGIN OF THE DOMBAR PHOSPHATES

The structural features of this phosphate deposit indicate its metasomatic origin. There are three possible sources of the phosphorus: 1) a primary precipitation out of sea water; 2) infiltration from younger phosphate beds above; 3) deposition by ascending solutions. We shall consider the probability of each.

1) The form of the ore body rules out a sedimentary origin of the phosphate. Precipitation of phosphorus compounds out of sea water would not have produced such a small and local concentration; it would rather have enriched a considerable area of deposits. Moreover, the phosphatization would have been associated with fine-grained sediments rather than with the accumulation of blocks where a preservation of chemical deposits is impossible. Nor can it be assumed that the lens is simply a heap of earlier phosphatized limestone fragments having originated, for example, on a Kiya uplift shoal. In that event, the phosphate boulders and blocks would have been scattered over a wider area, occurring wherever there are erosion products of the corresponding rocks. It also should be kept in mind that the lens cuts the boulder bed (Figure 13).

2) Quite plausible, at first glance, is the assumption of an infiltration of phosphorus from above, from phosphorite beds in Cretaceous deposits. Such a theory is rendered more attractive by published data on the existence of infiltration phosphates in Carbonaceous limestone karst terrain [2]. However, a more cautious approach is suggested by certain facts. The Dombar phosphates are not associated with a definite elevation, which should have been the case if their source had been in horizontal Cretaceous beds; and anyway, there are no sinkholes in the Dombar area.

Obviously, with an infiltration from above, metasomatic phosphates should have been quite common in the southern Urals where they would surely have been observed where the phosphate-carrying Cretaceous beds rest directly on Paleozoic rocks. No one, however, has seen that. It should also be kept in mind that the overall thickness of Upper Cretaceous phosphates is usually small (about 1 m) and that they are represented by thin layers with 17 to 19% P_2O_5 [1]. They could hardly have been the source for such a rich phosphate metasomatism as is present in Dombar.

3) Phosphate deposits requiring ascending solutions for their formation are so rare that the majority of geologists dealing with sedimentary phosphates will probably argue against such a possibility on general principles. Isolated examples of phosphate coming from below are known from literature. Thus, G. S. Dzotsenidze [3] has discovered secondary phosphatization of tuffs and basalts in the Mtavary formation; he believes that formation waters leached the phosphorus from the underlying interval primarily enriched in phosphorus, and deposited it under the basalt seal. In a number of places, no primary phosphate enrichment has been observed in the vicinity of phosphate lenses,

which led G. S. Dzotsenidze to assume a migration of solutions over considerable distances. It is of interest that springs flowing from the Mtavary formation still carry phosphorus compounds.

The Rezhevsk phosphates in Sverdlovsk Oblast', the Urals, are supposed to be hydrothermal [4-6]. Externally, as well as in chemical composition and microscopic texture, they are strikingly similar to those of the Dombar. They are developed in crystalline schists and marbles cut by granite. These phosphates form several isolated deposits, stock to pocket-like, in places associated with brown iron-ore deposits. They are friable in outcrops, and so hard at depth that they have to be blasted. Some deposits were mined to a depth of 15 m. V. N. Chirvinskiy [6] points out their similarity to Estremadura phosphates and assumes accordingly that both are of hydrothermal origin.

The occurrence and nature of Dombar phosphates rule out a primary sedimentary origin; an infiltration from above, too, is little probable. This leaves the deeper source of phosphate, which is in accordance with the latter's high concentration and localization.

Two variants of this hypothesis are possible: 1) the phosphorus was brought in during Assel time; i. e., contemporaneously with sedimentation; and 2) the phosphatization occurred after the Permian folding (rejuvenated deposit). The choice between the two depends on the shape of the deposit, at depth; i. e., whether it is a stock or the segment of a lens conformable with the enclosing Permian sediments. Until we have learned more about the shape of the ore body, the question of the source of its phosphorus as well as that of the time of metasomatism will remain open.

REFERENCES

1. Gimmel'far, B. M., Problema poiskov fosforitov v SSSR. [SEARCH FOR PHOSPHATES IN THE USSR]: In the book, "Voprosy geologii agronomich. rud". Izd-vo Akad. Nauk SSSR, 1956.

2. Ginzburg, I. I., and I. A. Rukavishnikova, Mineraly drevney kory vyvetrivaniya Urala. [MINERALS IN ANCIENT OXIDIZED ZONES IN THE URALS]: Izd-vo Akad. Nauk SSSR, 1951.

3. Dzotsenidze, G. S., Ob odnom sluchaye migratsii fosfata kal'tsiya v fosforitovom mestorozhdenii. [AN EXAMPLE OF THE MIGRATION OF CALCIUM PHOSPHATE IN A PHOSPHATE DEPOSIT]: Soobshch. Akad. Nauk GruzSSR, t. 15, no. 10, 1954.

4. Smirnov, A., Mestorozhdeniye fosforitov v Rezhevskoy dache na Urale. [PHOSPHATE DEPOSITS IN THE REZHEVSK DACHA, THE URALS]: Gornyy zhurnal, no. 3, 1924.

5. Fiveg, M. P., Mestorozhdeniye fosforitov na Urale. [A PHOSPHATE DEPOSIT IN THE URALS]: In the collection, "Fosfority SSSR". Izd-vo Geol. kom-ta, 1927.

6. Chirvinskiy, V. N., Mikroskopicheskoye i khimicheskoye issledovaniye fosforita iz dachi Rezhevskogo zavoda na Urale. [MICROSCOPIC AND CHEMICAL STUDY OF RZHEVSK PHOSPHATES, THE URALS]: Zap. Ural'sk o-va lyubit. Yestestvozn., t. 32, vyp. 2, 1913.

Geological Institute
Academy of Sciences, U. S. S. R.,
Moscow

Received, 23 April 1960

CERTAIN EPIGENETIC FEATURES OF TERRIGENOUS DEPOSITS[1] IN PLATFORM AND GEOSYNCLINAL PROVINCES

by

A. V. Kopeliovich, A. G. Kossovskaya, and
V. D. Shutov

nalysis of the principal rock-forming proc-s taking place during epigenesis calls for a minary consideration of certain features of eding stages responsible for the mineral position and constitution of terrigenous s.

'eathering is known to be an important phe-enon predetermining the mineral composi-of such rocks, both argillaceous and arena-s. Climatic conditions, duration, and in-ty of weathering determine the primary ral composition of sediments. Graywackes rkoses may be extreme examples of pri-/ terrigenous material, in rapid weathering mpanied by intensive erosion; quartz-kaolin-ocks, approaching the monomineral, may e products of long and intensive weather- A natural series of transitional types exists een these two groups.

has been recently determined that contrary e prevailing notion, a transfer of terri-us material, even over quite considerable nces, has almost no effect on its mineral position [13, 14, 17, 18, 20]. What does place in the transfer and deposition; i. e., diment genesis, is largely a differentiation aterial, by grain size, which determines the l structural-textural features of sediments. r mineral composition is naturally related eir granulometric types. Withal, the over-omposition of arenaceous and argillaceous nents in a basin is quite similar on the e to disintegration products of the source s.

hen follows a long period of post-sedimenta-alteration of deposits and rocks, with quite ual changes in their physicomechanical and ctural properties; the boundaries of individ-tages or phases of these transformations rather arbitrary, as yet, because of the lack lequate and objective criteria for their eation.

[1]) nekotorykh osobennostyakh epigeneza terri-ykh otlozheniy platformennykh i geosinklinal'nykh tey. pp. 18-31.

It was assumed until recently that diagenesis is the main stage of authigenic mineral-making in terrigenous sediments, a completely natural assumption in view of the fact that the intensive alteration of clastic material can take place only in the presence of a free exchange between highly mineralized ooze waters and bottom waters, and in the presence of active organic matter.

One of the most important factors is missing among these premises: time. Against the background of geologic time, the duration of a diagenetic period is only a short interval; it is therefore not surprising that the composition of minerals in recent clastic and argillaceous deposits turns out to be quite similar on the whole to that of clastic ooze dumped into the basin [18, 21]. Present-day sediments contain such unaltered components as volcanic glass, basic plagioclases, olivine, and leucite — all rare minerals, with the last two even missing in sedimentary rocks.

All this does not necessarily mean that no reworking of primary clastic material takes place in diagenesis, and no authigenic mineral-forming. Such processes do take place but they involve only the most "reactive" components of the sediment. Foremost among such components are clastic iron hydroxides which participate in the formation of a number of diagenetic ferruginous carbonates and sulfides. The terrigenous fraction undergoes a comparatively small transformation perceptible only in minerals with layered lattices, more specifically in clay minerals. Under certain geologic conditions, the clay minerals may undergo considerable alterations, as if determined by the physical conditions of the surrounding medium. Clastic minerals with a skeletal structure, even the least stable, appear to undergo only very slight changes, not yet observed microscopically by anybody.

The list of true diagenetic minerals is rather restricted, on the whole. It includes glauconite, vivianite, certain phosphates, and chamoisite; sulfides, however, as well as carbonates, may originate in both diagenesis and epigenesis; it is almost impossible to distinguish between the two

in a rock. For this reason, at the present state of our knowledge of the mineralogy of diagenesis, the degree of mineral alteration in a sediment or the appearance of some new mineral formations cannot be used as a criterion of the diagenesis-epigenesis boundary. Mineral forming processes, originating in diagenesis, change gradually to a long process of epigenesis and find their culmination in rocks rather than in sediments. By the same token, there is no such thing as the thickness of a diagenetic zone. It should be noted, in evaluating this thickness that the diagenetic process itself has been thought of apart from any specific environment.

No weight has been given to the consideration that in provinces of a rapid sedimentation, the diagenetic process is necessarily very short, especially with the sediment rapidly passing out of the zone of active interaction with water, even before an initial adjustment to new conditions. The situation is different in provinces of slow sedimentation, with the sediment subject to a prolonged interaction of ooze and bottom waters and undergoing considerable mineral changes reflecting the surrounding conditions.

Obviously, the diagenesis-epigenesis boundary can be drawn only on changes in the physical and mechanical properties of the sediment; i. e., on its transition from a fluid plastic to a solid-plastic state, when the sediment disappears as such, to become a rock [8].

The main factors determining the rock alterations in epigenesis are as follows:

1) an ever-rising pressure and some rise in temperature, both associated with subsidence;

2) interaction of rock and pore space waters, with the degree of mineralization increasing with depth, and with changing mineral composition;

3) the length of stay in the epigenetic zone, as determined by the geologic age of the rock;

4) the stress (in folded provinces), determining the so-called "thorough movements" within the rock, leading to considerable rises in temperature and pressure.

The epigenetic period may be divided into two stages: the initial and the deep-seated.

The zone of unaltered or argillaceous cement proper corresponds to the initial stage in sedimentary sections. Typically, both mudstone and sandstone cement carry true clay minerals, either inherited from the preceding rock-forming stage or originating at this very stage, most commonly as a continuation of earlier alteration processes in clastic components. Present along with such "pure" clay minerals as kaolinite, montmorillonite, and hydromicas, are (and usually in much greater amounts) extremely finely stratified members of assorted clay minerals, detectable only by X-ray analyses.

Rocks in the zone of argillaceous cement proper preserve to a considerable extent the textural and structural features acquired in sedimentation and diagenesis. A typical feature is the progressive downward increase in the degree of compaction of rocks, and the porosity reduction from 30 or 35% to 10 or 12%.

An important feature of this zone is the epigenetic solution of unstable clastic minerals: pyroxenes, amphiboles, and basic to intermediate plagioclases. It brings about typical solution forms: crenulate, step-like, etc., and i subsequent disappearance, down the section.

This phenomenon is particularly conspicuous in thick terrigenous sections with a single primary composition of clastic material. In that event, the composition of the heavy fraction is particularly diversified, in rocks of upper beds where it is characterized by the presence of many unstable minerals, up to pyroxenes. Going downward, the pyroxenes disappear, but amphiboles persist for some distance, until epidote alone remains among the unstable minerals; finally, the lowest beds carry only the so-called stable minerals: zircon, garnet, rutile, etc. (Figures 1, 2).

This typical zonation in the distribution of accessory minerals throughout thick clastic sections, first noted by F. Pettijohn [19], and now proven to be quite common, is formed at early epigenetic stages.

The composition of the main mineral line changes along with the accessory minerals; i. e., there is a gradual disappearance of feldspars, accompanied by a lowering in their basicity. It is superfluous to stress the importance of all these phenomena in various paleogeographic reconstructions; in determining the source of sediments; and consequently in general conclusions on the history of this or that region.

Intralayer solution of minerals is promoted by the presence of ground water, ordinarily containing hydrocarbonate, occasionally sulfate. Such waters are good solvents of unstable clastic minerals with skeletal structures (femic minerals, feldspars); they also promote the commonly radical alteration of minerals with layered lattices (trioctahedral hydromicas; feldspars), to form minerals more stable under the prevailing conditions.

In the disintegration of minerals, many elements pass into solution: first Fe, Mg, and Ca,

l to smaller extent Si, Al, and Na. Depend-; on conditions assuring the intensity of ex-ange between these and surface waters, the nponents are shifted about, more or less orously, and either are leached out or rticipate in the formation of a number of higenic minerals; i. e., carbonates, zeolites, l sulfates, which appear to be "replacing" disintegrating unstable minerals.

the rock-forming ones in the crystalline lattices of minerals. Under favorable conditions, these processes may lead to a concentration of certain ores [2].

The unaltered argillaceous cement zone in platform and geosynclinal provinces has a number of features of its own. Platform deposits are marked by a motley section consisting of

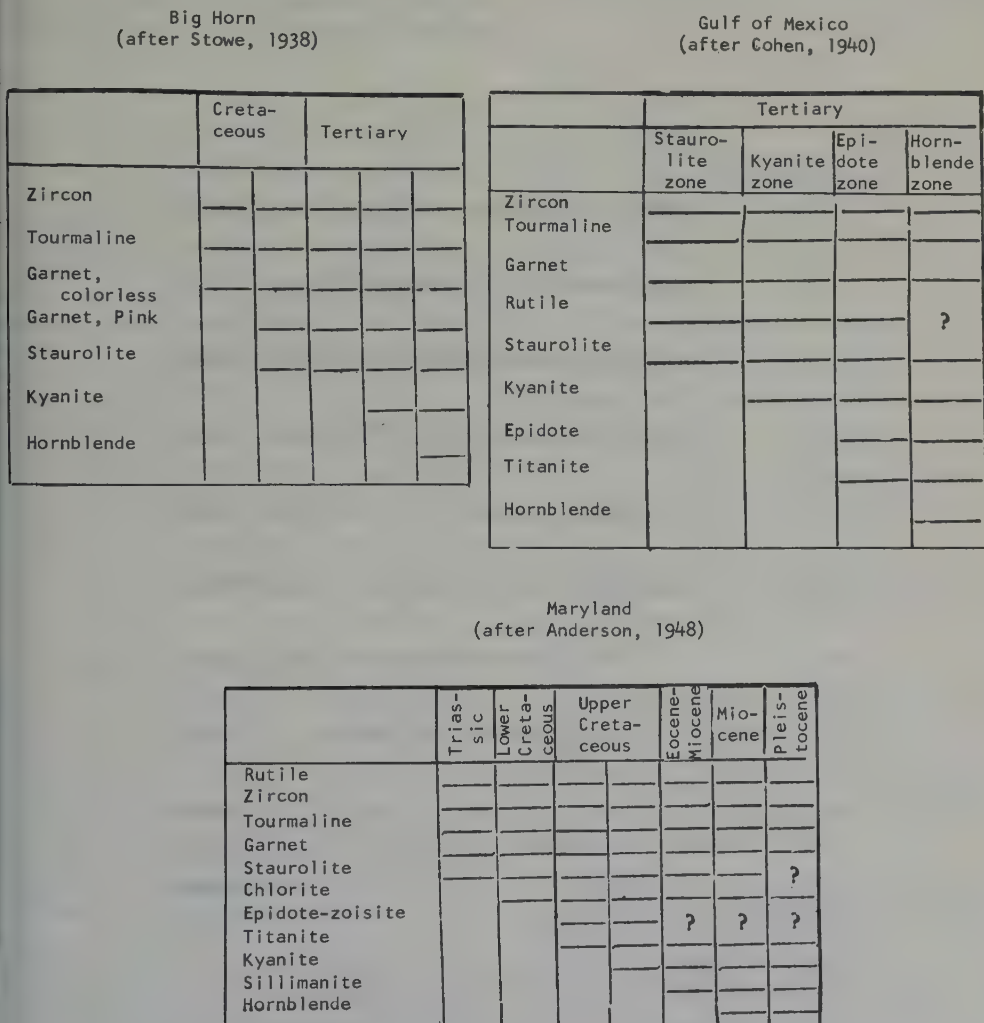


FIGURE 1. Zonal distribution of heavy minerals in deposits of various ages and regions.

Solid line marks the presence of minerals in more than 50% samples analyzed.

In some beds, originally rich in unstable nponents, these processes of intralayer ution, the liberation of "rock-forming" ele-its, and the development of authigenic for-ions, are quite extensive. The solution of umber of minerals puts into circulation cer-minor elements isomorphically replacing

rapid alternations of rock intervals with different composition. This diversity may be a result of changes in source rocks, particularly changes in degree of weathering [12]; as well as of facies changes. The latter is determined by the fact that the slow course of sedimentation and a long diagenesis create conditions under which the

sediments have time to be more or less thoroughly reworked and to acquire mineral features reflecting the physicochemical conditions of their environment [6].

At initial stages of epigenesis, rocks under a small load maintain their porosity and water-retaining capacity to a considerable extent. Here, the nature of alteration processes is determined by the type and composition of ground water. Quite often, these processes are but a continuation of diagenesis.

In geosynclinal provinces, the mineralogic and petrographic composition of rocks in a section is much more consistent. This is because, on the one hand, the rapid erosion of source rocks supplies the basin with fresh, only slightly weathered clastic material; on the other hand, with the rapid sedimentation and the correspondingly short period of diagenesis, the clastic material does not have time for an extensive alteration reflecting the physicochemical conditions of its environment. This is why the composition of clay mineral rocks in upper intervals

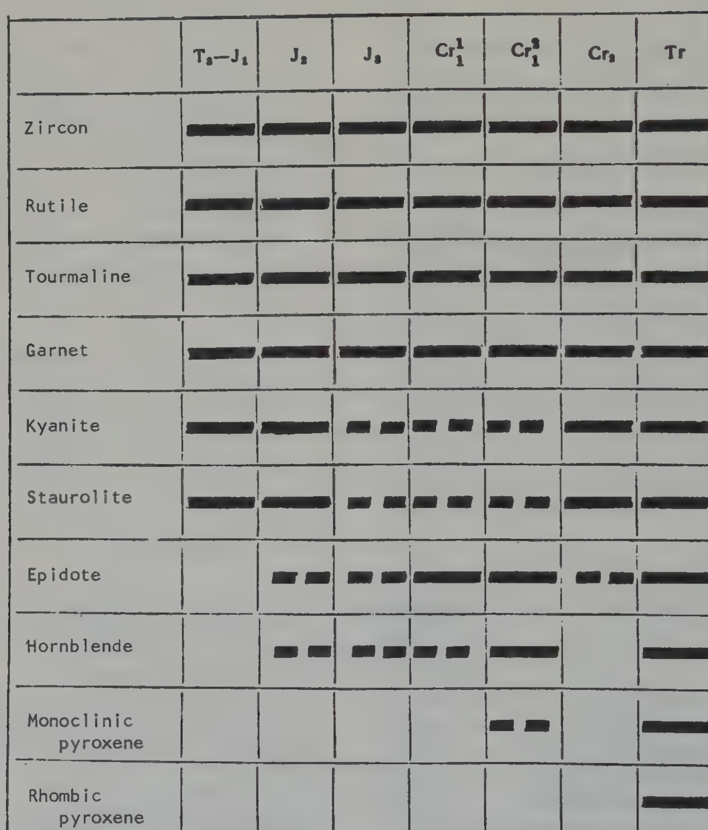


FIGURE 2. Mineral zonation in Mesozoic and Tertiary deposits of the Vilyuy trough and western upper Yana region.

Solid line - mineral present in over 50% of samples analyzed; dashed line - mineral present in less than 50% samples. After Pettijohn, 1957.

Thus, terrigenous sequences in platform provinces are characterized by a rapid alternation of rocks with definite individual parageneses of authigenic minerals formed during diagenesis and incipient epigenesis. This diversity of mineral parageneses is particularly well expressed in the composition of clay minerals in shale, and in the cement of sandstone. Monomineral bodies are not uncommon in sandstone.

of this zone differs little, as a rule, from that of the incoming original argillaceous material. What alterations there are take place during epigenesis and are best reflected in the lower intervals.

As a result, a geosynclinal section lacks the diversity in the alternation of mineralogic and petrographic rock complexes, of a platform

:tion. Nor does it contain any monomineral y formations.

This difference in diagenesis and epigenesis, platforms and geosynclines, may determine difference in parageneses of authigenic and y minerals, for terrigenous deposits in acent platform and geosynclinal provinces, med under similar facies conditions and m a similar source material. Mesozoic de- sits developed in the Vilyuy trough and the acent Verkhoyansk trough [7] are an example such a relationship.

What is the thickness of the zone of unaltered y cement, where the rocks preserve in full ir original sedimentary aspect? This thick- s is not consistent and depends on a number actors: tectonics, clastic material, the nposition of ground water, etc. Of para- unt importance, all other conditions being al, is the age of deposits, or the duration of effect of the overload. In young Neogene osits of the Apsheron Peninsula, the lower ndary of this zone is below 5000 m, as de- mined by drilling. In Mesozoic sections, as died in tests in East and West Siberia and Russian platform, the lower boundary is ly consistent, at about 2500 m. Paleozoic osits on the Russian platform are marked by urther thinning of this zone, down to 1300 to 0 m; finally, in Riphean deposits it has been ermined as less than 1 km. Thus, there ap- rs to be a sort of migration for the zone of y cement proper, depending on the age of osits (Figure 3).

n concluding the description of the initial genetic stage, we shall try to discribe its cific features. The course of the initial epi- etic processes is determined to a consider- e extent by the fact that the rocks still main- their high porosity and permeability, thus uring a free migration of solutions and ve exchange with surface waters. Because hat, the processes of incipient epigenesis largely a sort of continuation of diagenetic cesses, commonly "imitating" them.

The initial epigenesis, where the rocks still serve all their sedimentary features, is owed by a stage of deep-seated epigenesis n its essentially different processes of ration of sedimentary material, leading to emergence and development of new struc- l features and mineral parageneses which terate the primary sedimentary aspect of rigenous rocks and make them more like the amorphic.

The essential difference between the initial deep-seated epigeneses is that at a late e, the rocks lose their primary porosity considerable extent; because of the mass npaction and the closer contact of clastic ns, the overload stress distribution is radically changed. This stress is now trans- mitted by means of a peculiar framework of contacting grains; the stress distribution at the contact points is quite diversified because of differences in the contact areas [1]. Processes of pressure solution are operative in segments of considerable stress, resulting in a sub- stantially higher mineralization of pore-filling solutions, and supersaturation with rock-form- ing elements Si, Al, Na, K, etc., in segments of lower stresses. It should be emphasized that the composition and the ratio of elements going into solution and participating in authigenic min- eralization are here somewhat other than in the unaltered clay cement zone. By that time, the unstable minerals are usually gone; the most stable terrigenous rock components now go into solution although they were left intact in the preceding period: quartz, acid plagioclases, and potassic feldspars; it is these minerals that determine the predominance of silica, alumina, and other dissolved elements.

In connection with the mass pressure solu- tion of clastic grains, microelements pass into solution along with such principal rock-forming elements as Si, Al, Na and K. These micro- elements are present in crystalline lattices as microinclusions and isomorphic additions, such as Pb in a solution of potassic feldspars; Pb and Zn in the alteration and replacement of biotite; and Ba in the replacement of feldspars.

Under favorable conditions, these elements may migrate over considerable distances and accumulate in certain spots to give rise to ore concentrations [2].

Along with the mass solution of the principal clastic components of sandstone, the grains of quartz and feldspars are regenerated and en- larged, thus reducing the porosity and perme- ability and concommitantly the migration of aqueous solutions (the zone of arrested water ex- change and stagnant waters).

The rising mineralization of ground water and saturation with various elements brings about a development of complex exchange reactions and extensive metasomatic replacement. Parti- cularly affected are minerals with layered lattices, and above all the clay minerals. Po- tassium, silicon, and aluminum, emerging in interstitial solutions, affect the crystalline lattices of kaolinite, montmorillonite, and trioctahedral hydromicas, to bring forth di- octahedral hyromicas and minerals of the muscovite and dickite groups, more stable under the new higher-pressure conditions. The primary mineral composition of rocks deter- mines the composition of newly-emerging min- erals and puts a definite stamp on newly-formed structures [1].

Quartz sandstones, approaching monomineral, and quite common in platform provinces, have a

comparatively restricted assemblage of authigenic formations. The principal authigenic mineral is quartz in regenerated shells about clastic grains.

Authigenic minerals, formed at earlier stages of diagenesis and initial epigenesis, now undergo more thorough transformations. Kaolinite, commonly paragenetically related to monomineral quartz sandstones, is altered either to dickite or to a pyrophyllitic mineral, depending on conditions.

dioctahedral lattice with two silicon-oxygen layers and an octahedral aluminum layer between them.

The comparatively simple conformably regenerated mosaic structures, usually with a partial preservation of pores, are typical of quartz sandstones.

Arkosic sandstones are developed in both platform and geosynclinal provinces. Potassic and soda feldspars, most commonly in

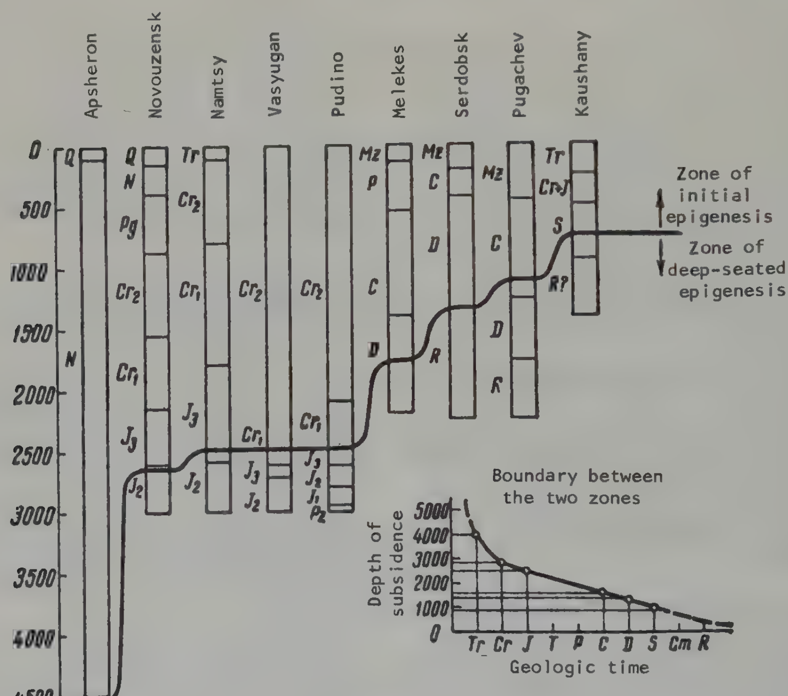


FIGURE 3. Thickness of the unaltered argillaceous cement zone (initial epigenesis) as a function of the geologic age of deposits.

Dickite is formed when the primary kaolinite cement occurs in interstices among the already formed regeneration shells which serve as bumpers against the effect of overload. Higher temperatures and time appear to be factors promoting the recrystallization and the structural organization of the primary kaolinite lattice.

The pyrophyllitic mineral is formed in partings enriched by clay, which appears to be hemmed in by partings of the mosaic structure sandstone. In these partings, at high pressures, clastic quartz grains are vigorously dissolved, with SiO_2 so obtained being used in the building of an additional tetrahedral silicon-oxygen layer over the two-layer kaolinite. The new three-layer mineral is an ideal model of a layered

regenerated shells about the clastic grains, are present among newly-formed minerals, in addition to the predominant quartz. Assorted titanium minerals (octahedrite, brookite, and sphene) and a few typical accessories; i. e., tourmaline, epidote, apatite, and occasionally zircon, are also present.

Minerals with layered lattices, particularly the clay minerals, are subject to thorough transformations. Kaolinite and montmorillonite change to dioctahedral hydromicas approaching sericite. Potassium for the hydromica lattice comes from feldspars dissolved under pressure (microcline and orthoclase as well as potassic and soda-feldspars) but maintaining their stability in the upper zone. It is to be noted

at these feldspars release potassium even at mparatively slight deformations of their ttice [5].

Trioctahedral micas (biotite type) are ex- emely unstable in this zone. The hydration d discoloration of biotite, initiated at the pre- ding stage, continues in this zone. It culmi- tes in a muscovitization of biotite, with the on so liberated fixed in hydroxides or in rruginous carbonates; or the biotite is de- mposed to chlorite of the aphrosiderite or pidolite types and a muscovite hydromica. is muscovitization of biotite appears to be complished by the entry into the mineral tice of excess aluminum from the solution of e same feldspars; this aluminum replaces the on and magnesium in octahedral layers.

Diagenetic glauconite common in both arkosic d quartz platform rocks is subject to similar erations. Just as kaolinite is altered depend- g on the effect of the pressure, so there seem be two trends in the alteration of glauconite. lorite, of the negative penninite type, is de- loped in closed porous segments, "shielded" om the excessive pressure effect. In those gments where glauconite shares the stress on e surrounding clastic grains, it changes to rruginous muscovite.

The greater diversity of the components in kosic sandstones is reflected in the greater ersity and complexity of their epigenetic uctures, as compared with quartz sandstone. ong with conformably regenerated structures, tform sections are marked by assorted stylo- c structures, while the geosynclinal sections e marked by incipient blastic structures.

Assorted polymictic sandstones, including aywackes, are known to be associated, as a e, with geosynclinal provinces and are less mmon in platform sections. The diversity of ir clastic material is reflected in their authi- ic formations and in certain peculiarities of ucture. As always, the composition of vly-formed components is closely related to nature of the clastic material. Assorted orites, ferruginous carbonates, minerals of epidote group, and titanium minerals, with r-present newly-formed quartz and albite widely developed in sandstones rich in frag- nts of basic and acid extrusives. A typical ture of these rocks is their appreciable iron ntent. The iron originates in the intensive selective solution of the vitreous bulk of rusive fragments, wherein silicon, aluminum, alkalies are leached and used up in authi- ic formations, while the iron is fixed in roxides and ferruginous carbonates [3].

A somewhat different paragenesis of authi- ic minerals is present in sandstones with dominantly acid extrusive fragments. Here, rtz is common, in regenerated fringes and in the hornfelsic cement. Chalcedony is also common, as well as albite in regenerated shells several times larger than the volume of clastic grains they enclose. The idiomorphic aspect of these regenerated grains, appreciably larger than the average clastic grains, lends a pseudo- porphyritic aspect to the rock.

It should be emphasized that structures of polymictic sandstones are usually appreciably different from those of arkosic and quartz sand- stones. As a result of the differential capacity of their components for pressure solution, peculiar incorporation structures arise, where- in the more stable clastic components (quartz, feldspars) are intruded into the less stable frag- ments of assorted rocks, including extrusives. A solution resistance order has been established as follows: quartz and feldspars — fragments of siliceous rocks — assorted metamorphic schists — extrusives. The last two components, being the most soluble, commonly constitute cement for the others. Apart from solution, differential plasticity of the components is another factor affecting the cementation. It often happens that cementation is caused by a mutual adjustment of clastic grains in a rock, rather than by the ce- menting substance itself which is generally quite scarce, if present at all [3].

In deep-seated epigenesis, argillaceous rocks turn to metashales (argillites). The loss of their capacity for swelling is associated with a reconstruction of the lattices of clay formations to a more stable structure of layered minerals which have lost their water-adsorbing capacity. The clay minerals proper; i. e., kaolinite, halloysite, and montmorillonite, are missing in this zone, having been replaced by dioctahedral hydromicas and chlorite; the first have been ob- served only in the upper half of the zone, and no longer as rock-forming components but rather as relicts in mixed-layered formations, along with similar muscovite-like minerals and chlorites.

There is one curious detail. The mixed- layered formations, so typical of clay in the diagenetic and initial epigenetic zones, are al- most nonexistent in rocks of the lower half of the zone. This is explained by a gradual pro- gressive crystallization and by the growing to- gether of individual grains. As the components grow larger, their X-ray analysis shows re- flections from the basal planes, with inter- mediate values for their components; in micro- scopic analysis, on the other hand, the increase in size reveals an intergrowth of chlorite and mica, undoubtedly developed out of the original mixed-layer formations.

Like the initial, the deep-seated epigenesis has features peculiar to conditions of platform and geosynclinal provinces. They are revealed in parageneses of authigenic formations as well as in the types of structure formed.

The specific features of parageneses for deposits in platform and geosynclinal provinces are determined by the inheritance of specific features of rocks developed at earlier stages, as pointed out before, as well as by differences in the conditions and factors of deep-seated epigenesis, in different structural provinces. On platforms, it is the long and cumulative effects of overload and a certain rise in temperature; in geosynclines it is the stress.

As mentioned before, platform sections are marked by the original diversity in the alternation of various rock types and by the occasional presence in them of monomineral clay formations. Hydromicatization is the principal alteration process for clay, in platform rocks, with dissolving feldspars the principal source of potassium, as pointed out before. Less common is the alternation of primary kaolinite to dickite and occasionally to pyrophyllitic minerals. Present in sandstones, along with albite, are such peculiarly platform authigenic formations as potassic feldspars, never present in geosynclinal rocks where only newly-formed albite has been observed.

The composition of newly-formed feldspars in rocks of different structural provinces is related to the lack of stability even in clastic grains of potassic feldspar, under intensive stress; this lack of stability precludes an authigenic alteration of that mineral in geosynclinal stages of deep-seated epigenesis. It also should be noted that the formation of typically stress-induced dioctahedral hydromicas and sericite, much more vigorous in geosynclinal rocks, leaves no excess potassium for the formation of authigenic orthoclase and microcline.

Another distinctive feature of geosynclinal rocks is the wide development of either aphrosideritic or repidolitic chlorite, in clay rocks as well as in sandstone cement, along with muscovite-like minerals. The presence of repidolite is explained, on the one hand, by the difference in petrographic types of geosynclinal rocks; viz., the better development of polymictic sandstones and graywackes rich in extrusive and femic mineral fragments which provide material for chlorite; on the other hand, by the rapidity of subsidence, preserving the unstable components at early diagenetic and epigenetic stages.

As noted before, the result may be that the same original material, buried in different structural provinces, will produce quite different parageneses of authigenic minerals.

Just as definite are details of the structural development of rocks. Mosaic structures emerging in the course of conformably regenerative alteration in clastic rocks are present in arenaceous rocks of platform provinces. Microstylolitization is an important structural factor in lower intervals of the deep-seated epigenetic zone. Related to it is pressure solution of contact faces of all rock-forming components which leads to the formation of pseudo-segregation segments as if imitating the typical schistose banding of true metamorphic rocks. The origin of such structures is related to the prolonged and continual effect of a confined pressure, the weight of the overload [1].

Added to conformably regenerative processes typical of upper intervals of this zone in geosynclinal provinces is a true blastic growth of clastic grains, which leads to the development of intricate webfoot and serrate bonds between the newly-formed grain shells, and to compound blasto-mosaic, merging structures. No microstylolites have been observed in sandstones.

It should be emphasized that the main factor determining the course of structural-mineral transformations, in deep-seated epigenesis, is pressure, with temperature a poor second.

In the progressive folding and subsidence of geosynclinal rocks, increasingly intensive alteration leads to a total loss of sedimentary features, strictly speaking, and to a complete recrystallization of the original clastic components, with a mass development of blastic structures and the appearance of typical segregation banded textures. This zone, studied in the Verkhoyansk geosynclinal section, has been designated the zone of metagenesis, corresponding to the transition stage from sedimentary to metamorphic rocks [4, 5].

Mineral associations of rocks from this zone have been "inherited" from long and deliberate alteration processes of sedimentary rocks, induced by the continually increasing vertical load, temperature, and stress. The typical association of newly formed minerals — dioctahedral (muscovite) mica, chlorite, and quartz — whose development is traceable from the uppermost zones of a geosynclinal section and the deepest platform horizons, obtains here its final mineralogic and structural expression.

The mineral composition and structural and textural features of rocks from this zone, especially from its lower intervals, are quite similar to those in the so-called green schist facies which is part of the upper zone of regional metamorphism [10, 11, 16]. The gradual transition from epigenetic to green-schist rocks associates the green schist facies with the metagenesis stage rather than with regional metamorphism.

The consistent composition of minerals with layer lattices, chlorite and muscovite in the green schist facies becomes understandable as we study the changes in the course of epigenesis for various clay minerals. Muscovite was

formed in the decomposition of clastic biotite micas, "reduction" of muscovite hydromicas, and a gradual hydromicatization of akolinite and montmorillonite. Chlorite was formed out of the same biotite micas and during the decomposition of a number of femic minerals (amphiboles, pyroxenes), in epigenesis.

Such is the alteration of the most common clay minerals, in deep-seated epigenesis and metagenesis. All newly-formed minerals originated in the gradual decomposition of other components; there are virtually no new formations originating in the interaction of minerals. This qualitatively new association emerges only in the biotite zone of regional metamorphism, as the result of a mass appearance of biotite produced by a reaction between muscovite and chlorite.

The emergence of this new association is related to a new factor in rock alteration, the considerable rise in temperature, which also determines all further changes in metamorphic rocks, as they pass through the stages of early and late metamorphism, with the consecutive emergence of the garnet, staurolite, and other zones of regional metamorphism. It is this zone that marks the beginning of truly metamorphic rocks.

Thus, a study of post-deposition alteration in sedimentary rocks shows that this is a compound process, proceeding by stages and leading finally to a gradual change of sedimentary formations to metamorphic formations. The stage nature of this process finds its reflection in the zonation of both geosynclinal and platform sections. The zones so differentiated correspond

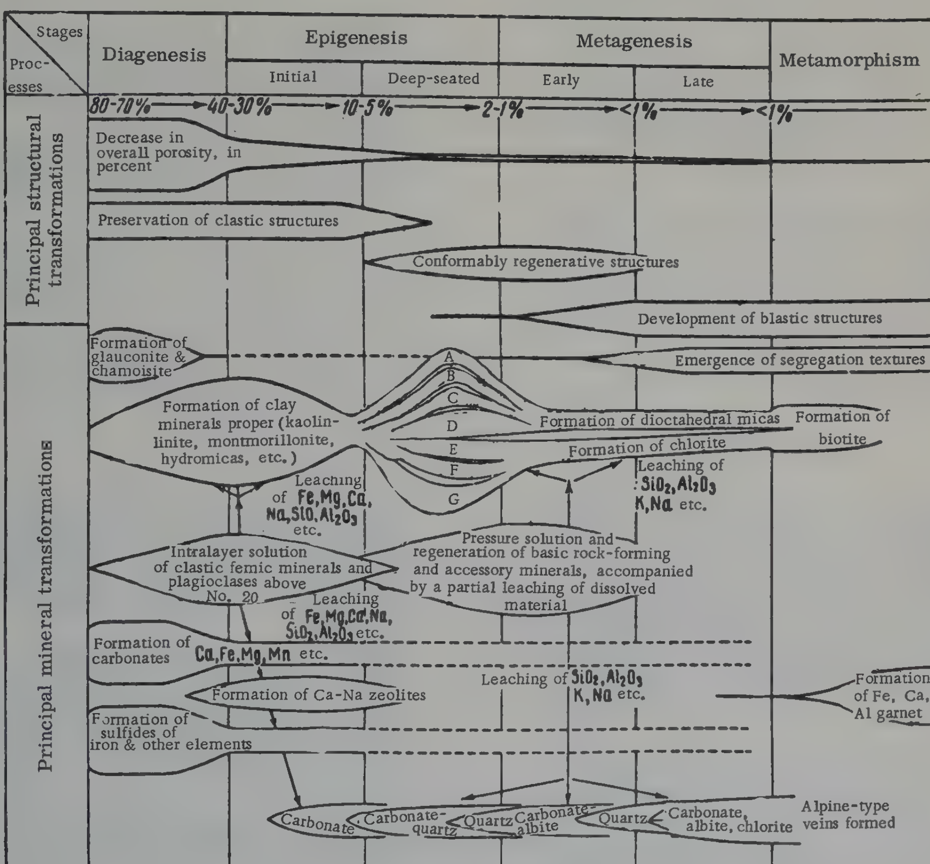


Figure 4. Structural and mineralogical transformations in various stages.

Code to Figure

A - Muscovitization of glauconite
B - Hydromicatization of kaolinite
C - Hydromicatization of montmorillonite
D - Dioctahedral mica preserved
E - Chlorite preserved
F - Chloritization of trioctahedral micas
G - Chloritization of glauconite and chamoisite

to individual stages and their smaller subdivisions. Each stage and substage has its own typical features of structural mineral transformations for sedimentary rocks (Figure 4). This makes it possible to designate the leading factors for each stage and substage and to gain better understanding of all details. For instance, the difference between the redistribution of material in the initial epigenesis and at later stages, in deep-seated epigenesis and metagenesis, becomes quite obvious. At an early stage, it is an intralayer solution of femic and of merely a few rock-forming minerals (plagioclases above No. 20), in reaction with pore solutions. At later stages, it is mass solution under pressure and recrystallization of the principal rock-forming minerals which constitute the framework of rocks.

In accordance with different causes of the redistribution of material, different associations of elements become involved in it, with migration paths and concentration regularities of their own. An understanding of these processes renders possible, even now, a new approach to the problems of origin and distribution of ore deposits for certain elements, such as Pb, Zn. Cu, etc., in sedimentary rocks.

It has been established that these zones of epigenesis and metagenesis are quite suitable for mapping, in both platform and geosynclinal provinces. The mapping of epigenetic zones may be used in solving some of the current problems of petroleum geology, such as forecasting the reservoir properties of rocks in basins under study.

REFERENCES

1. Kopeliovich, A. V., Osobennosti epigeneza peshchanikov mogilevskoy svity yugo-zapada Russkoy platformy i nekotoryye voprosy s nimi svyazannyye. [EPIGENETIC FEATURES OF THE MOGILEV SANDSTONE, IN THE SOUTHWESTERN PART OF THE RUSSIAN PLATFORM, AND SOME ASSOCIATED PROBLEMS]: Izv. Akad. Nauk SSSR, ser. geol., no. 11, 1958.

2. Kopeliovich, A. V., O proiskhozhdenii svintsovo-tsinkovoy mineralizatsii v drevnikh tolshchakh yugo-zapada Russkoy platformy. [ORIGIN OF ZINC-LEAD MINERALIZATION IN ANCIENT BEDS IN THE SOUTHWESTERN PART OF THE RUSSIAN PLATFORM]: Doklady, Akad. Nauk SSSR, t. 127, no. 1, 1959.

3. Kopeliovich, A. V., O strukturakh rastvoreniya v nekotorykh osadochnykh i effuzivno-osadochnykh porodakh. [SOLUTION STRUCTURES IN SOME SEDIMENTARY AND EXTRUSIVE ROCKS]: Izv. Akad. Nauk SSSR, ser. geol., no. 4, 1960.

4. Kossovskaya, A. G., and V. D. Shutov, Zony epigeneza v terrigennom komplekse mezozoyskikh i verkhnepaleozoyskikh otlozheniy Zapadnogo Verkhoyan'ya. [EPIGENETIC ZONES IN MESOZOIC AND UPPER PALEOZOIC TERRIGENOUS DEPOSITS OF THE WESTERN UPPER YANA REGION]: Doklady, Akad. Nauk SSSR, t. 103, no. 6, 1955.

5. Kossovskaya, A. G., N. V. Logvinenko, and V. D. Shutov, O stadiyakh formirovaniya i izmeneniya terrigennykh porod. [STAGES OF FORMATION AND ALTERATION OF TERRIGENOUS ROCKS]: Doklady, Akad. Nauk SSSR, t. 116, no. 2, 1957.

6. Kossovskaya, A. G., Faktory, opredelyayushchiye formirovaniye mineral'nogo sostava glin v usloviyakh platformy i geosinklinali. [FACTORS DETERMINING THE MINERAL COMPOSITION OF CLAYSTONE UNDER PLATFORM AND GEOSYNCLINAL CONDITIONS]: Doklady, Akad. Nauk SSSR, t. 129, no. 6, 1959.

7. Kossovskaya, A. G., O spetsifike epigeneticheskikh izmeneniy terrigennykh porod v usloviyakh platformennoy i geosinklinal'noy oblastey. [SPECIFIC FEATURES OF EPIGENETIC ALTERATIONS IN TERRIGENOUS ROCKS, UNDER PLATFORM AND GEOSYNCLINAL CONDITIONS]: Doklady, Akad. Nauk SSSR, t. 130, no. 1, 1960.

8. Lomtadze, V. D., Izmeneniye vlazhnosti glin pri uplotnenii ikh bol'shimi nagruzkami. [CHANGES IN THE MOISTURE CONTENT IN CLAY, IN COMPACTION UNDER HEAVY LOADS]: Zap. Leningr. gorn. in-ta, t. 29, vyp. 2, 1953.

9. Strakhov, N. M., Diagenez osadkov i yego znacheniye dlya osadochnogo rudoobrazovaniya. [DIAGENESIS OF SEDIMENTS AND ITS SIGNIFICANCE IN SEDIMENTARY MINERALIZATION]: Izv. Akad. Nauk SSSR, ser. geol., no. 5, 1953.

10. Turner, F., Evolyutsiya metamorficheskikh porod. [EVOLUTION OF METAMORPHIC ROCKS]: Izd-vo IL, 1953.

11. Harker, A., Metamorfizm. [METAMORPHISM]: ONTI, 1937.

12. Shutov, V. D., Epigeneticheskaya zonal'nost' paleozoyskikh i rifeyskikh otlozheniy Pachelmskogo progiba. [EPIGENETIC ZONATION IN PALEOZOIC AND RIPHEAN DEPOSITS OF THE PACHELMA TROUGH]:

Byull. Mosk. o-va ispyt. prirody, otd. geol., no. 6, 1960.

13. Andel, T. H. van, Provenance, transport and deposition of Rhine sediments. Wageningen, Veenman, 1950.

14. Andel, T. H. van, Petrology of Duravee River sands. Proc. III. Inter. Congr. of Sedimentology, 1951.

15. Andreatta, C., Über die Verglimmering der Plagioklase in der tektonischen Metamorphose. Tschermaks mineral und petrogr. Mitt., 1954.

16. Goldschmidt, V. M., Geologisch-petrographische Studien im Hochgebirge des südlichen Norwegens. Vidensk. Skr. Mat. Naturv. Kl., no. 10, 1921.

17. Milne, J. H., and J. W. Earley, Effect of source and environment on clay minerals. Bull. Amer. Assoc. Petrol. Geologists, vol. 42, no. 2, 1958.

18. Murray, H. H., and A. S. Sayypab, Clay mineral studies of some recent marine sediments of the North Carolina Coast. — Clays and clay minerals. Nat. Acad. Sci. Nat. Res. Council Publ., no. 395, 1954.

19. Pettijohn, F. J., Sedimentary rocks. 2-d ed. New York, 1957.

20. Russel, R. D., Mineral composition of Mississippi River sands. Bull. Geol. Soc. America, v. 48, 1937.

21. Weaver, C. E., Geologic interpretation of argillaceous sediments. Part I. Origin and significance of clay minerals in sedimentary rocks. Bull. Amer. Assoc. Petrol. Geologists, vol. 42, no. 2, 1958.

22. Weaver, C. E., A discussion on the origin of clay minerals. Clays and clay minerals. Nat. Acad. Sci. Nat. Res. Council, 1958.

Geological Institute,
Academy of Sciences, U. S. S. R.,
Moscow

Received, 15 June 1960

COAL MEASURES FACIES IN THE BURYATIAN A.S.S.R.[1]

by

L. P. Nefed'yeva

Coal measures of the Buryatian A. S. S. R. are associated with narrow and fairly long troughs trending mostly northeast, in the east and southeast, and almost latitudinally in the south and east. Geomorphically, these troughs are represented by river and lake valleys. The troughs themselves, as well as their sediments, are mostly Mesozoic, with some of them Cenozoic.

The principal Mesozoic troughs (Figure 1) carrying commercial coal deposits are the Gusinoozersk-Uda (including the Gusinoye Ozero coal deposit) and the Tugnuy. The latter contains the Olon-Shibirsk, Nikol'skoye, Erdem, and Kizhinga deposits. Located in the extreme western part of the republic are the Dzhida group of deposits: Bayangol, Salgino, and Kharakhuzhar.

Another type of coal measure is present in Cenozoic troughs, such as the Irkut River valley with the Zagotuy brown-coal deposit, and the south shore of Lake Baykal with its Pereyemnaya, Tankhoy, Polovinkinskoye, and other brown-coal deposits, along a narrow band of continental Tertiary deposits.

All coal measures of the Transbaykal region, including the Buryatian A. S. S. R., were formed under continental conditions. Lithologically, this section is represented by conglomerates, shales, carbonaceous rocks, and coal beds. Systematic stratigraphic works by G. G. Martinson (1954, 1955) and Ch. M. Kolesnikov (1956-1958) allowed those authors to propose the following stratigraphic column for the Transbaykalian continental Mesozoic:

Geologic age	Formations
Cr_1^{4-5}	Dain
Cr_1^{2-3}	Turgino-Vitim
$J_3 - C_1^1$	Ulan-ganga
J_2	Bukachach

[1]Fatsial'nyye tipy uglenakopleniya na territorii Buryatskoy A.S.S.R. pp. 32-44.

The coal is associated with the three lower formations. This column was used by the author in his coal petrography studies in many deposits; also used were Ye. P. Butova's data from her studies of the facies of coal measures. On the basis of these studies, and particularly those dealing with sedimentary facies, the following three types of coal accumulation have been identified in the Buryatian A. S. S. R.:

Type One has been described from the Tugnuy trough which is a compound syncline with the steep south limb and gentle north limb. The south limb is cut by a large normal fault. Standing out against the general easterly pitch of the trough, there are a number of synclinal structures of second order, separated by anticlinal flexures.

The coal measures were deposited here under typically continental conditions of an intermontane trough. According to Ye. P. Butova, river-channel, floodplain, delta, alluvial-cone, and lacustrine facies, are common among coal measures. As a result of detailed study, it has been determined that the accumulation of coal in the Tugnuy Valley was accompanied by a great influx of terrigenous fragments into the peat bog. The bulk of coal here is associated with the lower stratigraphic horizon, named the Bukachah formation, by G. G. Martinson and Ch. M. Kolesnikov.

The maximum thickness of this formation was penetrated by drilling in the central part of the trough, south of the Erdem Sovkhoz. To the east, the formation thins down, to wedge out completely at an anticlinal crest in the Kharauz village area, and to reappear in the Olon-Shibirsk syncline. In the central and eastern parts of the trough, the Bukachach formation is overlain unconformably by alluvial-deluvial deposits. In the west, it is conformably overlain by Ulanganga deposits, barren of coal.

A considerable number of coal beds, variable in thickness and structure, have been identified within the Tugnuy trough. The Tugnuy seam, varying from nonworkable to 7. 1 m thick, occurs in the central part (Erdem and Nikol'skoye

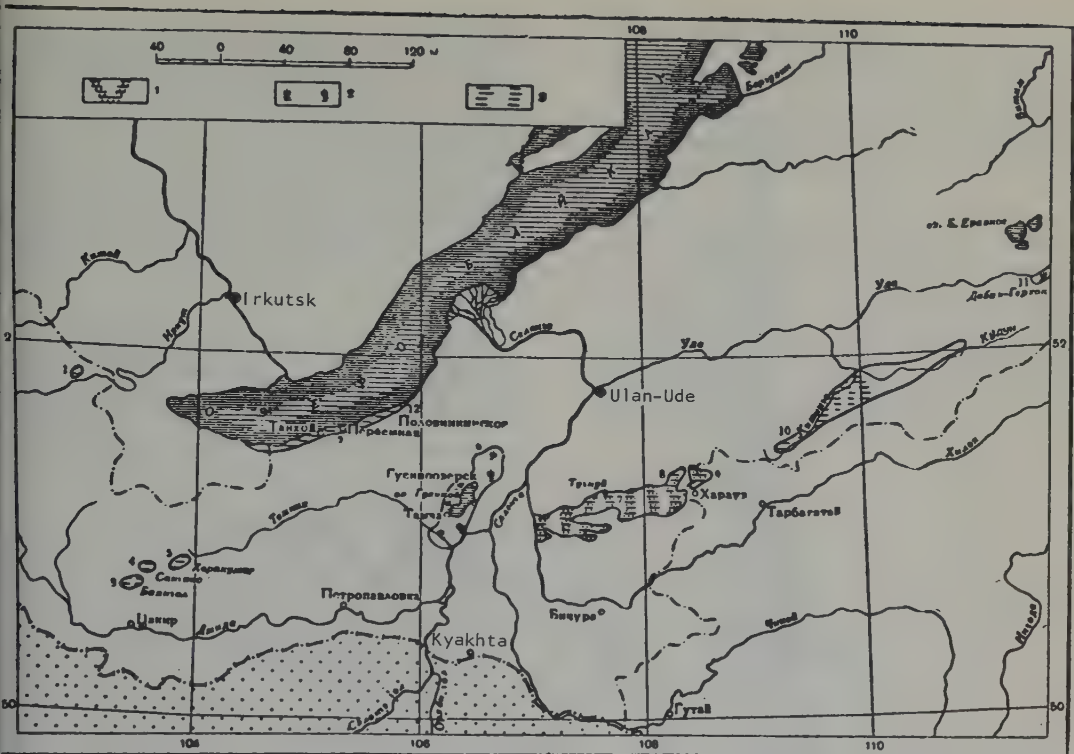


FIGURE 1. Distribution of coal facies in troughs of the Buryatian A.S.S.R.

Coal accumulation types: 1 - Type One, with the flowing-marsh facies predominant; 2 - Type Two, with the moderately wet-marsh facies predominant; 3 - Type Three, with the very wet marsh facies predominant
Numerals on map: 1 - Zagotuy deposit; 2 - Pereyemnaya; 3 - Bayangol; 4 - Sangino; 5 - Kharakhuzhar; 6 - Gusinoye Ozero; 7 - Tugnuy; 8 - Nikol'skoye; 9 - Kharauz; 10 - Kizhinga; 11 - Doban-Gorkhan; 12 - Polovinkinskoye.

eposits). Occurring stratigraphically higher n these two deposits, are several seams Sputnik, Nevyderzhannyy, Malyutka), even less onsistent than the Tugnuy and quite complex in tructure.

In the east of the trough (Olon-Shibirsk deosit, formerly known as the Kharauz) the section carries up to ten workable coal beds, quite omplex and inconsistent in structure, even ver short distances (maximum of 200 m). hese seams commonly split up and wedge out. he thickest seams are located in the northern art of the Olon-Shibirsk deposit.

As shown in Figure 2, the trends of coal eams are quite diversified; locally they are up o 40 m thick, with the thick lenses seen to split p and wedge out. The structure of coal beds in he Tugnuy trough is almost always complex, vith numerous seams separated mostly by oarse-grained rocks: sandstone, siltstone, and ccasionally by shale with small additions of lant remains. The sharp contacts between the oal and coarse-grained intercalations indicate rapid change of facies during coal deposition.

The Tugnuy trough houses two large lenticular coal sites: one in the central southern part (Erdem and Nikol'skoye deposits), the other in the northeast (Olon-Shibirsk). This distribution of coal is possibly associated with alluvial fans of intermittent streams and with peat bogs near to and within wide floodplains.

The lenticular shape of these coal deposits, with the complex structure of their commonly split-up seams coupled with the presence of coarse, clastic material at their top, base, and in the intercalations, as well as the peculiar aspect of their component facies, all renders the Tugnuy trough illustrative of type-one coal accumulation.

The study of coal facies afforded means of identifying the several types of coal-making. Our differentiation of coal facies is based on the degree of inundation and circulation in the original peat bogs, the presence of mineral impurities in coals; their stratification, texture and luster; also the microtexture and the qualitative relation between gel and fusain in coal (Table 1). A general knowledge of the sedimentary

environment is also quite important for an interpretation of coal facies. Accordingly, the following environments have been recognized for the accumulation of peat in the Tugnuy trough: 1) freely flowing marshes; 2 - sluggish flowing marshes; and 3) slightly wet marshes. Given below is a brief description of each.

The freely flowing marsh facies is the most typical of Type One coal accumulation in the Tugnuy trough. Mainly the dull, semidull, less commonly semilustrous coals are formed under such conditions. Their granular texture is determined by the small terrigenous mineral fragments evenly dispersed in gel of the groundmass, as seen in thin sections. These fragments are mostly quartz and feldspars.

FIGURE 2-a. Coal bed outcrops in the Olon-Shibirsk deposit.

The horizontal stratification of these coals is determined by the few millimeter-thick argillaceous partings. The semidull, horizontally-stratified coal of this facies, durain-clarain in microtexture, consists of a gel groundmass with a scattering of extremely fine terrigenous fragments, microspores, and bark tissue.

The amount of mineral impurities and cutinized elements is greater in dull durain coals than in the semidull. The same is true for the semilustrous, clarain type.

Features common to all coal types of this facies are their horizontal stratification usually marked by argillaceous parting and less commonly by an alternation of layers with different contents of microcomponents; a strongly decomposed and homeogenously gelled groundmass; and a very low content of fusainized plant remains. The strong decomposition of the fusainized plant tissue appears to be associated with the abundance of water in the peat bogs as well as with the considerable amount of mineral impurities which might have acted as catalysts in the formation of gels. The great importance of mineral impurities in present-day and fossil peat bogs has been stressed in recent publications.

Thus, K. K. Lebedev [6] states on the basis of extensive chemical studies, "Changes in the composition of humic acid, in individual layers, are in their turn directly affected by the mineral components of peat." I. A. Amosov [2] has come to the conclusion that "mineral matter and solutions, upon their arrival at a peat bog, determine the formational environment for different petrographic types."

Works of L. M. Sapozhnikov and I. N. Nikolayev [10] contain interesting experimental data concerning the effect of mineral impurities on the properties of coals. It has been demonstrated that "the intensity of the effect of different mineral impurities is quite different, but the nature of this effect is the same." The authors conclude that "mineral impurities have a catalytic effect on those groups of reactions which are common to pyrolysis of various coal types," and that certain mineral impurities quite vigorously accelerate the decomposition of plant remains.

The very wet, flowing marshes were widely eveloped in the Tugnuy Valley; the flow was ore permanent and less obstructed in the orth (Olon-Shibirsk) where semidull to dull, orizontally stratified coals are present.

The facies of sluggish marshes is represented y semilustrous to semidull, finely banded, non-ratified coals. Microscopically, these are arains and durain-clarains, with a transparent elled groundmass and numerous inclusions of ark tissue and microspores.

Because of the less abundant and stagnant ater in the original peat bogs, the content of sainized tissues in these coals is higher than coals from freely flowing bogs. This facies transitional from the freely flowing bogs to ightly wet bogs with their coal high in fusain.

The intensity of flow is reflected in the nount of terrigenous mineral impurities in the oal body. Argillaceous partings are missing, ere, indicating the absence of a large influx of ineral material during the peat accumulation. oals formed in such sluggish bogs are develop-d in the central part of the Tugnuy trough.

The facies of slightly wet bogs is represented y semidull, dull, and rare semilustrous coals. hey are thin-banded, with a horizontal strati-cation determined by fusain intercalations easured in centimeters. The semidull, thin-anded, horizontally stratified coal corre-ponds microscopically to clarain-durain with transparent groundmass carrying numerous nses of fusain and xylan, distributed parallel bedding. The formation of fusain and xylan as promoted by the aerobic conditions pre-ailing because of periodic draining of the peat og.

Microscopically, the dull, thin-banded, hori-ontally stratified coal is a xylan-fusain durain, ith a small amount of mineral impurities in ellular openings of fusainized plant tissue. he dull variety is less common than the semi-ull, both occurring in the eastern part of the ugnuy trough (Olon-Shibirsk).

Altogether seven genetic coal types have been entified in the Tugnuy trough, the most com-on being semidull and semilustrous coals of eely flowing marshes. These coals occur in e central and eastern parts of the Tugnuy alley.

A considerable amount of terrigenous min-als was brought to peat bogs of the Tugnuy alley; their presence, coupled with the abun-ance of water, promoted the formation of these eculiar granulated coals with strongly decom-osed plant material. These two main factors, e mineral impurities and the abundance of ater, have determined the specific coal facies, ith their fairly uniform botanical composition.

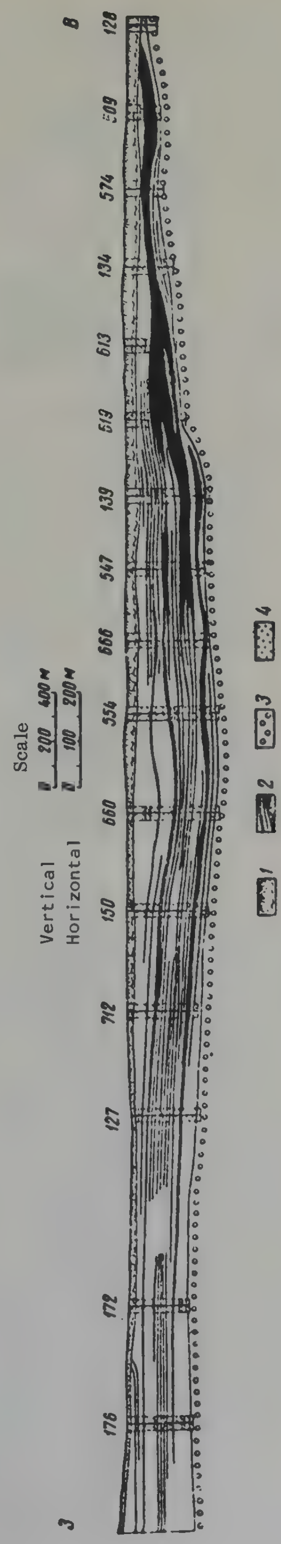


FIGURE 2-b. Cross-section along line IV - IV.

1 - Alluvial; 2 - coal beds; 3 - conglomerate; 4 - sandstone; numerals are borehole Nos.

Table 1

Peat Facies in Coal Deposits of the Buryatian A. S. S. R.

Facies	Genetic coal types	Microtexture of coals	Coal stratification	Presence of fusain tissue	Mineral impurities	Distribution by deposits
I. Freely flowing marshes	Dull and semidull, less commonly semilustrous, striated	Durains and clarain-durains with a large amount of mineral impurities and macrospores	Horizontal marked by millimeter-thick shale partings	None or very little	Numerous, small quartz inclusions dispersed in the transparent coal groundmass	Tugnuy, Nikol'skoye, Olon-Shibirsk, Kizhinga
II. Sluggish marshes	Semilustrous to semidull, finely banded	Clarains and durain-clarains	Nonstratified	Present in small amounts	Few quartz inclusions in transparent groundmass	Tugnuy, Nikol'skoye, Olon-Shibirsk
III. Slightly inundated marsh	Semidull to dull, seldom semilustrous, banded	Clarain-durains and durains, rarely durain-clarains	Horizontal, marked by millimeter-thick fusain partings	Present in large amounts	Quartz fills up cellular openings in fusainized plant tissue	Olon-Shibirsk; Gusinoye Ozero.
IV. Stagnant wet marshes	Lustrous to semilustrous, seldom semidull, striated and lenticularly banded	Clarains, durain-clarains, rarely clarain-durain	Nonstratified	Very small amount	Mineral impurities in isolated grains	Bayangol, Gusinoye Ozero, Daban-Gorkhon, Kizhingin, Pereyemnaya

Type Two coal accumulation is common in the Gusinoye Ozero coal area, one of the largest of the troughs (see Figure 1). The coal measures here are over 2000 m thick, represented by typically continental deposits: sandstone, siltstone, and shale, of the river channel, lacustrine, and marsh facies.

A detailed stratigraphic subdivision of the Gusinoye Ozero section was done by Ch. M. Kolesnikov [4] who designated the Bukachach (J_2), Ulanganga J_3 + Cr (v), and Turgino-Vitim Cr_1 (v-ap) formations. The maximum coal development in the Gusinoye Ozero trough is associated with the Ulanganga and Turgino-Vitim formations. Over 60 workable seams are known here, all more consistent in thickness and continuity than those in the Tugnuy trough. Their enclosing rocks are mainly siltstone and shale, in contrast to sandstone in the Tugnuy trough. These finer-grained rocks are of a lacustrine type.

Common among the Gusinoye Ozero trough deposits are sandstones of alluvial facies. Regularities in the distribution of facies, here, are described by Ts. O. Ochirov [9], from his special lithologic studies. According to him, alternating siltstone, shale, and coal predominate in the lower coal measures of the Gusinoye Ozero trough, with subordinate thin sandstone beds locally carrying pebbles. The importance of sand increases going up the section, with an "accompanying appearance of fine pebble conglomerates and an increasing thickness of intercoal intervals." Associated with this sequence are coal seams up to 10 m thick (northern section). Peat bogs on the Gusinoye Ozero trough did not provide as steady a foothold as those in the Tugnuy trough.

The following facies have been identified in the Gusinoye Ozero coal area: 1) stagnant bogs; 2) bogs with an average degree of inundation; 3) slightly wet bogs; 4 - freely flowing bogs (quite restricted in area). Given below is a brief description.

The stagnant bog facies is represented by lustrous, semilustrous, and semidull, striated, and lenticularly banded horizontally stratified coals. The lustrous varieties carry much vitrainized xylem and a transparent groundmass with occasional yellow microspores. Also present are structural vitrains with cellular openings filled up with humus.

In their microtexture, the semilustrous horizontally stratified coals correspond to clarains consisting of numerous lumpy lenses fringed with cuticle.

The semidull, striated, and lenticularly-banded horizontally striated coals are represented by alternating clarain and durain layers, several centimeters thick.

Typical diagnostic features of stagnant bog coal facies, of all degrees of luster, is the considerable degree of decomposition in their plant material, although smaller than in the Tugnuy coals; also the absence of fusainized plant remains, and the very small amount of cutinized bodies. Such a combination of microelements can be explained by the stagnant conditions which prevented the removal of organic matter, in the colloidal state, as well as any large influx of spore and mineral impurities.

The facies of stagnant bogs with an average degree of inundation is represented by semilustrous to semidull, horizontally-stratified coals. This stratification is caused by millimeter-thick partings of fusain.

The semilustrous, striated, horizontally-stratified clarain coal contains a considerable amount of bark tissue, lenses of xylan and fusain, and a few microspores. The volume of xylan and fusain lenses increases in semidull striated coals. Vitrainized plant fragments in coal preserve their outlines. The semidull striated coal differs from the semilustrous, striated type, by the presence of intercalations enriched in lenses of xylan and fusain.

All types of coal of this facies are characterized by the presence of plant remains preserving their morphologic outlines. Mineral impurities here are few. Proceeding along with anaerobic decomposition in bogs with average inundation was aerobic oxidation of plant remains, which accounts for the higher content of xylan-fusain in these coals.

These coal facies are most common in the eastern and northeastern parts of the Gusinoye Ozero area. Fairly common here also is the slightly inundated bog facies represented by dull, semidull, rarely semilustrous, striated fusain coals.

A more detailed description of the latter facies is given under Type One. In the Gusinoye Ozero area, the content of fusain and xylan in cellular openings is lower than in the Tugnuy coals. The freely flowing bog facies is represented here by dull to semidull coals, very rarely by semilustrous, striated, horizontally to lenticularly stratified, carrying pelitic material and a small addition of angular quartz fragments. A detailed description of the freely flowing bog facies has been given above.

This facies is poorly represented in the Gusinoye Ozero area. The enclosing rocks are mainly siltstone, shale, and carbonaceous shale.

The general aspect of the Gusinoye Ozero coal measures, as well as the texture, lithology, and facies of its coals, makes this a type locality for type two coal accumulation.

Located in the northeastern part of the Gusinoye Ozero trough is the Daban-Gorkhon deposit (Figure 1) which also can be assigned to Type Two. One of its coal seams, drilled through in borehole No. 1, is over 80 m thick. It is made up largely of semilustrous to semi-dull coals, striated and horizontally stratified, with numerous small inclusions of vitrainized xylem. The main component of these coals is bark tissue, with cutinized elements a poor second. These coals were formed chiefly in bogs with an average abundance of water, where the gel-forming processes were accompanied by fusainization; the poor circulation interfered with the influx of mineral impurities. The enclosing rocks are represented by siltstone and shale. The facies of Daban-Gorkhon coal measures are similar to those of the Gusinoye Ozero, with an obvious prevalence of river and lacustrine facies.

A distinctive environment for coal deposition is indicated by the Bayangol deposit, with its single coal horizon with a peculiar texture and petrographic composition. This is where we established our Type Three of coal accumulation. Structurally, the Bayangol deposit is a small trough (Figure 1), with the coal measures partly covered by younger basalt flows. The coal measures are Jurassic, about 500 m thick, and consist largely of lacustrine deposits. Their coal content is expressed locally in a single seam traced areally, by mining and drilling, over about 3 km^2.

along its periphery, without any noticeable splitting up.

Two facies have been identified in this coal unit: 1) a stagnant marsh, almost a lake; and 2) a freely flowing marsh with an influx of terrigenous minerals.

The stagnant marsh facies is represented by homogeneous semilustrous, nonstratified coals with a semiconchoidal fracture. Microscopically, these are clarains with a homogenous transparent groundmass and inclusions of bark tissue, locally fringed with cuticle, as well as a few microspores and resinous bodies. Mineral impurities are represented by isolated fine quartz grains. Fusain is missing. These coals were formed in a very wet marsh, almost a lake, as witness the strong decomposition of plant remains and the absence of fusainized tissue. Isolated algae are present in these coals. The facies of very wet, stagnant marshes is widespread, in this unit.

The freely flowing marsh facies, with an influx of terrigenous minerals, is represented by full, striated, horizontally-stratified coals. They have a resinous luster; under the microscope, they correspond to durain with a transparent groundmass carrying numerous resinous bodies and fairly coarse angular quartz grains. Accordingly, this coal may be called resinous liptogiolite with a considerable content of

FIGURE 3. Distribution of the coal seam in the northern field of the Bayangol deposit.

1 - coal boundaries; 2 - area of distribution; 3 - faults.

In the north, this coal seam occurs in isolated irregular patches (Figure 3). It is directly overlain by sapropelitic shale with a considerable amount of decomposed to partially preserved Pila algae.

In the west, the coal horizon is simple in structure; in the west, it is broken up by as many as four shale and siltstone layers. Its base is represented usually by siltstone and carbonaceous shale. This horizon wedges out

mineral impurities. The origin of such coals appears to be related to the free flow in the marsh with a considerable influx of quartz grains. This facies is rather restricted, with dull, striated coals present in small lentils in the middle part of the unit.

The occurrence in the Bayangol deposit of redeposited coal consisting of clarain and durain pebbles in an argillaceous groundmass is of interest. The formation of such

Table 2

Coal Facies in the Buryatian A. S. S. R.

Types of coal accumulation	Coal regions and deposits	Age of coal deposits	Coal content: Thickness of coal measure	Coal content: No. of workable seams	Coal content: Typical features of coal deposits	Predominant sedimentary facies	Predominant coal facies	Most common genetic types of coal	Chemical characteristic of coal types[1]	Remarks
One	Tugnuy coal region; Erdem, Nikol'skoye, Olon-Shigirsk deposits	$J_2 - Cr_1$	900	1-10	Multiple seams, mostly broken	Alluvial cones and river valleys	Freely flowing marshes	Semidull, striated horizontally stratified	$A^c = 20.74$ $V^r = 41.11$ $C^r = 70.75$	Average of 10 analyses
Two	Gusinoye Ozero coal area: Zagustay deposit, northern section; deposits Tamchin, Kholbol'dzhin, Daban-Gorkhan;	$J_2 - Cr_1$	2000	60	Multiple seams, mostly continuous	River and lacustrine	Marshes, average inundation	Semilustrous, banded, horizontally stratified	$A^c = 8.34$ $V^r = 42.33$ $C^r = 78.12$	
Three	Bayangol, Kizhingin deposits; Baykal coal region (Pereyemnaya deposit)	$J_2 - J_3$; C^r T_r	500 1180 over 1000	1 2 8-20	Lenticular	Lacustrine	Stagnant marshes, quasi-lacustrine	Semilustrous, nonstratified	$A^c = 10.86$ $V^r = 39.4$ $C^r = 75.76$ $A^c = 9.9$ $V^r = 69.08$ $C^r = 52.13$	Bayangol deposit: average of 6 analyses Pereyemnaya deposit: average of 5 analyses

[1]Chemical analyses of first two types, by G. L. Stsepinskaya (Laboratory of the Geology of Coal, Academy of Sciences U.S.S.R.) ; data on Type Three, after V.A. Larina [5].

"conglomeratic"[2] coals is associated with the erosion of a coal seam and redeposition of reworked coal within the same coal area. A similar intraformation erosion of coal was observed in the Ekibastuz deposits, Kazakhstan.

Thus Type Three coal accumulation is characterized by the predominance of lacustrine facies, a lenticular form of the coal deposit, and a strong ascendence of the very wet stagnant marsh facies in coals. Here belongs the Kizhinga deposit (Figure 1) where exploration has revealed the presence of two coal bodies separated by a barren sand-conglomerate interval. The two workable coal seams of this deposit are made up of semilustrous striated coals of the very wet, stagnant marsh facies, and to a smaller extent of dull, striated coals of the freely flowing marsh facies. The dull varieties contain a large amount of resin bodies, as has been noted for the Bayangol. In analogy with the Bayangol trough, an extensive development of lacustrine deposits may be anticipated here. Belonging to the same type are Tertiary coals in the Transbaykal region, with their predominantly lustrous coals of the very wet, stagnant marsh facies. Occurring among the Baykal coals are lentils with algae, difficult to identify because of the strong oxidation of coals.

SUMMARY

The three types of coal accumulation identified from the Buryatian A. S. S. R. will undoubtedly be encountered in other Transbaykalian deposits. Future comprehensive studies should further substantiate the designation of these types and possibly identify new types of coal accumulation throughout the region.

The differences in these types have been determined by the structure of their troughs of deposition, which has also determined the paleogeographic conditions and facies of coal measures and coal horizons. The determination of regularities in facies types in various coal fields of the Buryatian A. S. S. R. permits forecasting the locations of different coals. Thus, coals of Type One are marked by a higher content of mineral impurities and belong mostly to the flowing marsh facies. The distribution of Type Two coals suggests the presence of a number of coal facies. The main components of Type Three are two different facies: 1) a very wet, stagnant marsh; and 2) a freely flowing marsh. Local allochtonous formations occur in both.

The data of this article are presented in Table 2 which shows that a definite form of coal deposit corresponds to each type of coal accumulation. These accumulation types differ in the facies of their coal measures and their coal horizons. The most common genetic types differ among themselves in their ash content and to a certain extent in their content of volatiles and hydrogen.

The predominance of this or that facies in coal measures and coal horizons has been determined by specific features in the development of corresponding troughs.

The present view of the Transbaykal region as a mobile platform is substantiated by the presence in the Buryatian A. S. S. R., of the three types of coal accumulation.

REFERENCES

1. Ammosov, I. I., Osonovnyye prichiny neodinakovogo sostava i svoystv iskopayemykh ugley. [PRINCIPAL CAUSES FOR THE DIFFERENCES IN THE COMPOSITION AND PROPERTIES OF COALS]: Tr. In-ta goryuch. iskop. Akad. Nauk SSSR, 1953.

2. Ammosov, I. I., Geologicheskiye faktory i svoystva iskopayemykh ugley. [GEOLOGIC FACTORS AND PROPERTIES OF COALS]: Tr. In-ta goryuch. iskop. Akad. Nauk SSSR, t. 3, 1954.

3. Butova, Ye. P., Litologo-fatsial'naya kharakteristika uglenosnykh otlozheniy doliny reki Tugnuy. [LITHOFACIES DESCRIPTION OF COAL MEASURES IN THE TUGNUY RIVER VALLEY]: In the book, Materialy po izuch. proizvodit. sil Buryat-Mongol'sk. ASSR, vyp. 2, 1956.

4. Kolesnikov, Ch. M., Stratigrafiya mezozoyskikh uglenosnykh otlozheniy Tugnuyskoy depressii. [STRATIGRAPHY OF MESOZOIC COAL MEASURES IN THE TUGNUY TROUGH]: Izd-vo Akad. Nauk SSSR, 1959.

5. Larina, V. A., Ugli Buryat-Mongol'skoy ASSR, ikh svoystva i vozmozhnyye puti ispol'zovaniya. [COALS OF THE BURYAT-MONGOLIAN ASSR, THEIR PROPERTIES AND POSSIBLE UTILIZATION]: In the book, Materialy po izuch. proizvodit. sil Buryat-Mongol'sk. ASSR, vyp. 1, 1954.

6. Lebedev, K. K., O roli mineral'nykh komponentov v formirovanii torfyanykh otlozheniy. [ROLE OF MINERAL COMPONENTS IN THE FORMATION OF PEAT DEPOSITS]: In the book, Genezis tverd. goryuch. iskop., 1959.

[2] "Conglomeratic" is used in quotes, because of the small size of clarain and durain pebbles.

7. Nefed'yeva, L. P., Petrograficheskiy sostav i usloviya obrazovaniya ugol'nykh plastov Gusinoozerskogo mestorozhdeniya. [PETROGRAPHIC COMPOSITION AND THE FORMATION CONDITIONS OF COAL HORIZONS IN THE GUSINOYE OZERO DEPOSIT]: In the book, Materialy po izuch. proizvod. sil Buryat-Mongol'sk. ASSR, vyp. 3, 1957.

8. Nefed'yeva, L. P., Metodika izucheniya fatsial'noy izmenchivosti ugol'nykh plastov. [METHODS OF STUDYING THE FACIES CHANGES IN COAL BEDS]: Tr. Labor geol. uglya Akad. Nauk SSSR, vyp. 8, 1958.

9. Ochirov, Ts. O., Litologicheskiy sostav i usloviya nakopleniya uglenosnykh otlozheniy Gusinoozerskogo uglenosnogo rayona. [LITHOLOGIC COMPOSITION AND THE FORMATION CONDITIONS OF COAL DEPOSITS IN THE GUSINOYE OZERO COAL AREA]: Tr. Labor geol. uglya Akad. Nauk SSSR, vyp. 8, 1958.

10. Sapozhnikov, L. M., and I. N. Nikolayev, Vliyaniye organicheskikh i mineral'nykh dobavok na svoystva kamennykh ugley v plasticheskom sostoyanii. [THE EFFECT OF ORGANIC AND MINERAL IMPURITIES ON THE PROPERTIES OF COALS IN THE PLASTIC STATE]: Tr. In-ta gor-yuch. iskop., t. 2, 1959.

Laboratory of Coal Geology,
Academy of Sciences, U. S. S. R.,
Leningrad

Received, 1 June 1960

VOLCANISM IN THE KURILE ISLANDS[1]

by

Ye. K. Markhinin

This article deals with the general history and the present state of Kurile volcanism. It notes that the present intensive solfatara activity as well as the formation of sulfur deposits and alunitization zones are related to the latest post-calderal volcanic activity expressed in the formation of annular and radial faults, acid extrusive domes, and minor near-surface intrusions.

* * * * *

1. INNER AND OUTER ZONES OF THE KURILE ISLAND ARC

The Kurile chain, which extends for over 1000 km, in a northeasterly direction along the Eurasian-Pacific boundary, is a double island arc consisting of inner and outer zones. The outer zone embraces the northeastern extremity of the island of Hokkaido, approximately from the Kusiri coal deposits to the Nemuro Peninsula [5], the Lesser Kurile Ridge (Tanfil'yev, Zelenyy, Polonskiy, Sikotan islands, etc.) and is traceable in submarine relief, with a few breaks, to its continuation in Kamchatka.

The inner Kurile arc begins almost in the central part of Hokkaido where it joins the transverse Yezo arc. It trends northeast from there, through the volcanic areas of Daisetsu and Akan and the Sirotoko Peninsula on Hokkaido, on through the Greater Kuriles islands, from Kunashir in the southwest to Paramushir and Shumshu in the northeast, and on to Kamchatka.

The two arcs are different, first of all in their morphology. The main feature of the outer zone is its comparatively low and level relief. Its mountain chains, mostly Cretaceous and Paleogene in age, have been almost leveled; they are generally not higher than 400 m, and extend parallel to one another and to the general Kurile trend. In contrast to that, the Greater Kurile arc islands are characterized by the presence of sharp-peaked ranges made up largely of Neogene volcanics and rising to 1500 m, and by high tablelands; i. e., mesas formed of Quaternary flows, 600 to 700 m high, and finally by remnants of extinct Quaternary and now active volcanoes, commonly higher than 1500 m.

Another difference between the two zones is the present volcanic activity in the inner zone as contrasted with the absence of it in the outer zone. Finally, the outer zone is marked by large gravity anomalies, in contrast to relatively small anomalies in the inner arc. That phenomenon has been recently noted by Japanese students Ch. Tsubon, M. Minato, K. Yagi, and M. Hunanashi [5]. Extensive geophysical studies carried out by the Pacific Expedition of the Institute of the Physics of the Earth, Academy of Sciences, U. S. S. R., in connection with the I. G. Y., have confirmed these differences in gravity anomalies for the inner and outer arcs.[2] Thus, the boundary between the two can be drawn on the abrupt change in gravity anomalies.

These manifest differences between the two arcs undoubtedly have deep-seated causes. A closer study of the geologic structure and history of the Kurile arc reveals that the geologic history of its inner and outer zones has been substantially different. While the outer zone is made up mostly of fossiliferous Cretaceous and Paleogene deposits, these rocks are not present in the inner zone. It is probable that Neogene deposits in the Greater Kuriles rest directly on Paleozoic and early Mesozoic formations, similar to the Hidaka series of Hokkaido. This probability is enhanced by the analogy between the Greater Kurile ridge and the inner zone of the northern Honshu arc. It appears that the Cretaceous and Paleogene were periods of erosion, in the Greater Kurile arc. On the other hand, Neogene formations, unknown as yet from

---

[1] Vulkanizm Kuril'skikh ostrovov. pp. 45-58.

[2] Preliminary information on some of the geophysical anomalies in the Kuriles area has been obtained by the author from Ye.I. Galperin.

the Lesser Kurile arc, are quite thick in the Greater Kuriles. There are reasons to believe that the Neogene was a time of erosion in the outer Kurile zone. This substantiates the earlier conclusion by M. Minato, K. Yagi, and M. Hunanashi, arrived at largely from their study in northern Honshu, that tectonic movements in the inner and outer structural zones of northern Honshu and Kurile arcs had opposite signs during certain periods of their geologic history. It appears that a deep fault passes between the two zones, reflected in the abrupt change in gravity anomalies. Relative movements along the fault have occurred and still do occur.

2. THE HISTORY OF VOLCANISM IN THE KURILES

Volcanism has played a great role in the development of the Kuriles. Its history, as determined by Soviet and Japanese geologists, is presented in Table 1.

Three cycles of volcanism are identified in the Lesser Kurile ridge: the Cretaceous, Tertiary (Paleogene?), and Quaternary. We assign to the Cretaceous cycle an interval designated as the Matakotan formation, by Sasa, in 1936, and occurring at the base of the Lesser Kurile section; and the gabbro intrusions which cut Cretaceous deposits but not the Tertiary.

The Metakotan formation presents an alternation of volcanic conglomerates and sandstones, with flows of augitic andesite-basalt. The conglomerate fragments are mostly rounded, and are derived from this basalt. Individual boulders are as much as 0.5 m across. According to Yu. S. Zhelubovskiy, the Matakotan section is at least 400 m thick. It trends to the northeast, dipping 25° to the southeast, and is overlain with slight angular unconformity by typical sedimentary rocks. The latter carry, especially in their lower part, some volcanic material in the sandstone, shale, siliceous rocks, and marl, with a scanty Senonian fauna.

This formation was first described as Sikotan, by Sasa, and then as Malo-Kuril'skaya, by Yu. S. Zhelubovskiy; its thickness is about 200 m. Its origin marks a subsidence and a break in surface volcanism in the Lesser Kurile ridge. The gabbro intrusions, which we believe to have been manifestations of mighty volcanic processes during Matakotan time, cut and alter the Senonian deposits. These intrusions are 1 to 3 km across. They are mostly of gabbro and basic diorite and consist largely of basic plagioclase and assorted dark minerals — olivine, augite, hypersthene, and biotite.

After a certain interval, surface volcanism in the Lesser Kurile ridge surged up with new vigor, in the Tertiary (Paleogene?). The Tertiary cycle is represented here by flows and lava breccias of andesite and andesite-basalt, tuffaceous conglomerate, and numerous dikes. Occurring in the conglomerate, along with andesite and andesite-basalt fragments, are pebbles of gabbro from Upper Cretaceous intrusions. These rocks trend northeast, with dips as high as 20°. According to Yu. S. Zhelubovskiy, the Tertiary volcanics are 500 m thick.

After a phase of folding of Cretaceous and Paleogene rocks, and following a considerable break in sedimentation, accompanied by erosion and denudation (Paleogene?), the Lesser Kuriles appear to have been the site of a strong flare-up of Quaternary volcanism, which we designate as a separate cycle. Its formations rest with sharp angular unconformity on the Cretaceous and Paleogene, and they are represented by two-pyroxene andesite and olivine basalts which make up a number of collapsed volcanic structures in Sikotan Island, many of which are periclinal to the centers of volcanic structures.

We recognize the Miocene, Pliocene, and Quaternary volcanic cycles in the Greater Kurile arc [3, 4]. The Miocene cycle rocks have been strongly altered, hydrothermally and pneumatolytically, as well as closely folded, and broken up by numerous faults. They are overlain, with major angular unconformity, by the Pliocene cycle rocks, slightly altered and usually gently dipping at 10 to 15°. The Quaternary rocks are either horizontal or slightly periclinal, away from the centers of young volcanic massifs.

The Miocene volcanic cycle is represented by assorted extrusives (andesite to rhyodacite), intrusions of quartz diorite, and vein rocks.

Assorted undifferentiated volcanics are quite common in Kunashir, Urup, and Igurup islands, where they are represented by dacite, rhyodacite, and their tuffs, which are commonly propylitic. This section is cut by intrusions of quartz diorite and numerous dikes of paleotype andesites and andesite-basalts. It warrants special attention as the repository of a sulfide mineralization, probably related genetically to granitic intrusions. It is no less than several hundred meters thick. It has been tentatively assigned to the Miocene, in analogy with the "green tuffs" widely developed in northern Japan.

Quartz diorite intrusions, known from Paramushir, Urup, and Kunashir, occupy small areas. They have a weathered aspect; their feldspars are pelitic, with the dark minerals replaced by chlorite. The common development of porphyritic and microaplitic textures suggests the hypabyssal origin of these bodies. The age of these quartz diorites is tentatively assumed to be Upper Miocene [3].

Table 1

Igneous Section in the Inner and Outer Zones of the Kurile Island Arc

	Greater Kurile Ridge (inner zone)			Lesser Kurile Ridge (outer zone)		
Geologic age	Formation	Volcanic cycles	Predominant direction of tectonic movements & principal phases of folding	Formation	Volcanic cycles	Predominant direction of tectonic movements & principal phases of folding
Quaternary	Basalt, andesite-basalt, andesite, andesite-dacite, and dacite, forming the present structures Unconsolidated volcanic andesitic and dacitic products, redeposited by the sea Andesite and andesite-basalt flows and necks	Quaternary		Volcanic processes missing Flows of two-pyroxene andesite and olivine basalt, in the extant volcanic structures	Quarternary	
Tertiary – Neogene – Pliocene	Extrusive rhyodacite Basic tuffaceous conglomerate and sandstone	Pliocene		Erosion Formations of this age are unknown	(?)	
Tertiary – Neogene – Miocene	Vein rock series: A) Veins and dikes of propylitic rhyodacite. B) Veins and dikes of propylitic rocks from the andesite and basalt group. C) Quartz-sulfide veins Intrusion of quartz diorite Assorted propylitic volcanic formations (from andesite to rhyodacite), undifferentiated	Miocene				
Tertiary – Paleogene	Erosion Formations of this age are unknown	(?)		Veins and dikes of augite andesite Flows, lava breccias, and agglomerates of augite andesite and andesite-basalt Flows and dikes of basic augite andesite	Tertiary (Paleogene)	
Cretaceous – Senonian	Erosion Formations of this age are unknown	(?)		Gabbro and diorite intrusions with a wide range of component dark minerals Andesitic lava flows, lava breccia, and tuffaceous conglomerate	Cretaceous	

The Miocene vein series is represented in e Greater Kurile islands by dikes of acid and sic rocks and by quartz-sulfide veins. Dikes propylitic rhyodacite and dacite are present ong the northwestern coast of the Kunashir and, in the Prasolov Point area. Their thick- ss ranges from 0.5 to 12 m, and they are sociated with a massif of quartz diorite. They t this massif; consequently, they are younger an it, although in places they preceded the rmation of the andesite and andesite-basalt in series. Dikes of basic rocks are quite mmon, ranging in thickness from a few ntimeters to many meters. Sulfide-quartz ins in the hydrothermally and pneumatolyti- lly altered Miocene section (more specifically, kuchayevo, Valentinenskoye, and Zolotoy yuch deposits, in Kunashir Island) appear to related genetically to granitic intrusions. ey carry copper-lead-zinc and gold-silver neralization. I. P. Aver'yanov lists among eir ore minerals, pyrite, sphalerite, galena, alcopyrite, molybdenite, argentite, gold luride, native gold, bornite, chalcocite; nong vein minerals, apart from quartz: rite, kaolinite, and siderite. Vein contact erations are represented by pyritization, olinitization, and silicification. The vein ckness usually does not exceed 10 cm. The end of Miocene veins and dikes is variable, ost commonly to the northwest, with steep gles of dip.

The Pliocene cycle is represented mainly by faceous conglomerate with pebbles of quartz orite, and basic tuffaceous sandstones. They e known from a number of Greater Kurile ands, where they locally carry a Neogene ına and commonly contain intercalations of sic extrusives. Their total thickness reaches ndreds of meters, in individual sections. esumably Pliocene tuffaceous sandstones in e Goryachiy Plyazh area, Kunashir Island, are t by a small rhyodacite intrusion. We have served rhyodacite outcrops also at Point Reefs d along Turin Creek, in the same island. The int Reefs rhyodacites are perlitic and may be interest as a source of perlite raw material. cording to measurements made by G. A. spelova on several samples we have collected om the Goryachiy Plyazh extrusion, they show reverse residual magnetism, typical of the of the Pliocene and the base of the Quatern- y. It is probable that these rhyodacites be- ng to the very close of the Pliocene volcanic cle.

Three principal periods are discernible in aternary volcanism of the Greater Kurile dge: first, the formation of andesites and desite-basalts, now found at the base of any volcanoes and exposed in many places der high marine terraces (100 m and over); cond, the formation of unconsolidated vol- nic-sedimentary sections of andesite to cite composition, which make up the high marine terraces; and third, the formation of volcanic structures which make up the present relief and consist of calcareous extrusives of varying basicity from basalt to dacite.

The first period lavas, which form level plateaus, are marked by a reverse magnetism, according to preliminary data, at least in some places. Such are, according to G. A. Pospelova, three of our samples from the South-Kurile point lavas. This appears to suggest that these lavas occur near the Pliocene-Quaternary boundary. Submarine volcanism is associated with the second period, because the sandy pumice beds making up the high marine terraces were deposited in water. The volcanoes which supplied material for these deposits, specifically the Golovin and the volcanoes in the areas of Lake Peschanoye, Kunashir; Krasivoye, Iturup, etc., apparently were unstable, at that time, and their active cones were rapidly destroyed by the sea. Their present structures were formed after an uplift, when the volcanoes stood high.

It appears then that volcanic eruptions in the Kuriles have been associated with both uplift and subsidence. In the Cretaceous and Paleogene, the outer zone of the Kurile arc subsided and its volcanic activity accompanied this movement. At the same time, the inner zone was rising. An inversion took place at the onset of the Neogene. The movement was reversed in both zones; this time, it was the inner zone that was affected by Neogene subsidence with the accompanying volcanic eruptions. In the Quaternary, both zones were subjected to recurrent uplift and subsidence. Only isolated flare-ups of volcanism took place at the beginning of the Quaternary, in the Lesser Kurile ridge, which has subsided in recent time. Conversely, the Greater Kurile ridge underwent vigorous volcanic activity, with the presently existing volcanoes having been active during the entire uplift of the Greater Kuriles.

3. RECENT VOLCANISM IN THE KURILES

By recent volcanism we mean volcanic phenomena which have led to the present landforms of active and extinct Quaternary volcanoes. Thirty-nine active volcanoes, with well-expressed structures, one of them submarine, are known in the Kuriles [2]. Their eruptions are mostly of an explosive nature, with the ejection of large volumes of pyroclastic material which is annually dumped into the sea. Lava flows, blocky as a rule, are subordinate. It is impossible to determine any regularity in the change of their composition in the course of time. It has been observed that even adjacent volcanoes, during simultaneous eruptions, ejected different lavas (e.g., dacite lavas of the Mendeleyev vs. basalt lavas of the Tyatya).

Table 2

Composition of Condensed Solfatara Vapors and of Hot Springs

Components gm/liter	Condensates of solfatara vapors			Hot spring waters		
	Ebeko volcano $t \approx 115°$	Mendeleyev volcano $t=100°$	Golovnin volcano $t=100°$	Ebeko volcano $t \approx 60°$	Berutarube volcano $t=30°$	Golovnin volcano $t=98,5$
H	0.0742	0.0027	0.0061	0.0008	0.0035	0.0350
NH_4	0.005	0.0002	0.0004	0.0006	0.0010	0.0015
K	0.2358	0.0637		1.3961	0.0098	—
Na	—	—	0.1033	—	0.2070	—
Ca	0.1535	0.1648	0.2101	0.1040	0.3643	0.1045
Mg	0.0139	0.0165	0.537	0.0497	0.0693	0.0305
Al	0.009	0.0260	0.0300	0.080	0.1810	0.1173
Fe	—			—	0.3910	0.0010
Fe	0.002	—	—	0.045	0.0710	0.2070
Mn	—	—	—	—	—	0.0002
Cu	—	—	—	—	—	—
Ti^{+4}	—	—	—	—	—	—
Total cations	0.4844	0.2739	0.4036	1.6762	1.2670	0.4970
Cl	3.141		0.0801	1.8922	0.3671	0.0133
SO_4	0.269	0.0767	0.0927	1.2963	3.0752	1.5321
HSO_4	—	0.0106	0.0225	0.0815	0.6822	2.9876
F	0.007	—	—	0.0024	0.0010	—
Br	—	—	—	—	—	—
NO_3	—	—	—	0.0018	—	—
Total anions	3.4170	0.0873	0.1953	3.2742	4.1255	4.5330
CO_2	—	—	—	—	—	—
H_2SiO_3	0.0851	0.0207	1.1088	0.3000	0.260	0.4150
H_2S	—	0.0190	0.0663	—	—	—
H_3PO_4	—	—	—	—	—	—
HBO_3	—	—	—	—	—	—
S	2.740	—	—	—	—	—
H_3ASO_3	0.0026	—	—	—	—	—
Total mineral	3.7290	0.4009	0.7740	5.2504	5.65	5.4450
pH	1.02	2.56	2.21	3.0	2.45	1.31

[1] Ye.P. Ryabichkina and Ye.P. Podol'skaya, Analysts.

Table 2 (continued)

ntent of Hydrogen Sulfide and Sulfurous ases in Solfataras on the Slope of An Extrusive Cone (Golovnin Volcano)

Gases	in gm/liter	% of total
H_2S	0.012	5.5
SO_2	0.113	43.5
SO_3	0.133	51.0

'e.P. Ryabichkina, Analyst.

It appears, however, that basic lavas are followed, in time, by more acid types).

The most important event in the development of many present volcanic structures was the formation of calderas, which always dampened the volcanic vigor. Over half of the active volcanoes preserve this calderas, either intact of partly destroyed. The number and size of calderas of extinct volcanoes are even greater. There is no evidence against a collapse origin of the Kurile calderas.

In following G. Williams, Van Bemmelen, and the majority of volcanologists, we believe that the major Kurile calderas have originated as follows. A partial removal of the content of a

Table 2 (continued)

Composition of Associated Gases (Golovnin Volcano)

Sampling location	Components					
	CO_2	H_2	CH_4	N_2	$\frac{He+Ne}{N_2+i}$	$\frac{Ar}{N_2+i}$
Teploye Ozero	93.42	0.70	0.95	4.33	0.01233	1.802
Large caldera Lake	93.84	1.20	1.74	3.22	0.02418	1.728

K.P. Florenskiy, Analyst.

Table 2 (continued)

Composition of Altered Rocks

Components	Sampling locality			
	Mendeleyev Volcano		Golovnin Volcano	
	relatively slightly altered andesite	interior of an altered andesite block	periphery of an altered andesite block	decomposed andesite
SiO_2	57.88	79.22	90.92	45.64
TiO_2	0.80	0.98	1.08	0.38
Al_2O_3	15.56	2.50	2.87	0.17
Fe_2O_3	—	0.01	6.26	0.25
FeO	0.74	—	—	—
MgO	—	0.14	0.34	—
CaO	2.73	0.20	0.06	—
Na_2O	0.67	0.65	—	—
K_2O	0.19	0.38	—	—
SO_3	14.79	—	—	2.30
S	—	1.67	0.09	—
$(+H_2O)+(-H_2O)$	6.05	8.06	4.48	51.85
Total	99.41	100.35	100.06	100.09

V.G. Sil'nichenko, Analyst.

volcanic magmatic chamber, during vigorous eruptions, proceeded faster than the space so vacated could be filled by magma rising from a deeper source. The volcanic structure collapsed under its own weight, along an annular fault zone, and a caldera was formed at the surface. The largest Kurile calderas (L'vinaya Past' and Kudryavyy) are about 10 km across and as much as 80 m in depth. Thus the volume of pre-collapse volcanic hollows is measured in tens of cubic kilometers (it has been demonstrated that the formation of calderas through foundering is possible only when the magnetic chamber is located at shallow depths, not exceeding a few kilometers). Such hollows may originate only in an assimilation of lateral rocks by magma, and after their removal to the surface during eruptions. Quite typical of the post-calderal activity in the Kurile volcanoes is the formation of extrusive domes, usually of acid andesite or andesite-dacite, with 58 to 65% SiO_2. A study of the internal structure of these domes has shown them to be more complex than the standard onion or fan-shaped types.

For some typical data on the composition of solfataras and altered rocks see Table 2 (from collections by G. S. Gorshkov, S. I. Naboko, and the author).

The present vigorous solfatara activity and the formation of sulfur springs and zones of alunitization are often associated with the formation of the annular and radial faults, at the close of the volcanic activity, and with the appearance of acid extrusive domes and minor shallow intrusions (one such intrusion appears to be responsible for a domal uplift in lacustrine deposits within the Golovnin caldera).

Almost 75% of all active Kurile volcanoes have solfataras represented by gas-steam glows, hot springs, and small mud volcanoes. The solfatara temperature is usually about 100°C, reaching 200 or 300°C at times. Their chemical composition is fairly similar for different volcanoes, varying somewhat depending on the escape conditions for volcanic gases. Subaerial solfatara blows are marked usually by the abundance of water vapor and carbon dioxide, with the typical presence of hydrogen sulfide, sulfurous gases, and hydrogen chloride. These components dissolve in their passage through water, which explains the anion composition for waters of hot springs and warm crater lakes.

Predominant among the associated gases of hot springs and crater lakes is carbon dioxide, with some nitrogen, methane, and hydrogen. The strongly acid waters (pH = 0. 5-3. 0) obtained in the solution of the volcanic gas components in meteoric waters react vigorously with their reservoir rocks and leach out the latter's metals. This is the cause of the cation content of these waters (Table 2). Formed in the course of rock alteration and of the "evaporation" of solution are efflorescent minerals (halotrichite, pickeringite, alunogen, sulfates, and alum). It is probable that the presence of some of the cations of such elements as boron in thermal waters, in addition to the anions, may be explained by their being brought in by volcanic gases. Sulfur is formed in the oxidation of hydrogen sulfide, either at the surface or near it, in all solfataras. In particular, this process is responsible for the accumulation of sulfur-carrying oozes at the bottom of some warm crater lakes. It should be noted that

Table 3

Volcanic Eruptions in the Kuriles

Volcano	Date	Nature of eruption
Berg Volcano	Winter 1951-1952	Ash ejections
Karpinskiy Caldera	November 5, 1952	Ejection of dark gas billows with ash
Krenitsin Peak	November 12-19, 1952	Lateral, essentially explosive eruption, terminated with the appearance of a cone
Sarychev Peak	November 9-19, 1956 August to October 1954	Formation of hot landslides Ash puffs; formation of a lava plug
Zavaritskiy caldera	November to December 1957	Ash and bombs blown up as high as 7 or 8 km. Appearance of an extrusive dome

Table 4

Main Types of Quaternary Lavas in the Kuriles

Rocks	Composition of incrustations				Composition of groundmass			Structural features		Chemical composition					
	Pl (%An)	Pr	Ol (%Fa)	Q	Pl (%An)	Pr	n glass	volume of incrustations, % of total	Principal structures of groundmass	SiO_2	Fe_2O_3+ +FeO	MgO	CaO	Na_2O	K_2O
Basalt	70—90	Augite	20—30	—	55—82	Augite	1.543—1.551	18—50	Intersertal, micro-doleritic, hyaline	50.84—51.75	11.26—11.53	4.02—4.89	10.21—10.32	2.12—2.48	0.96—1.07
Andesite-basalt	60—80	Augite-hypersthene	20—30	—	48—55	"	1.528—1.539	2—28	Transitional to hyalopilitic and pilotaxitic	52.25—56.56	7.07—12.74	3.55—4.94	7.84—10.32	2.10—3.51	0.40—1.24
Andesite	54—70	"	—	—	45—52	" Hypersthene	1.510—1.523	14—44	Hyalopilitic, seldom pilotaxitic	56.00—58.00	8.03—9.82	2.06—3.86	7.97—8.66	1.97—3.86	0.48—0.67
Andesite-dacite and dacite	40—68	"	—	Q	28—45	Rare augite Rare andesite	1.505—1.510	25—41	Hyalopilitic, microlitic, quasi-spherolitic	32.37—64.68	6.46—8.62	1.54—2.46—	5.02—6.12	2.26—3.46	0.49—0.95
Rhyo-dacite	37—50 Rare	Rare hyper-sthene	—	Q	27—32 Rare	—	1.488—1.505	11—19	Crystalline, quasi-spherolitic	74.00	3.2	3.62	2.60	2.79	0.86

rocks rich in iron sulfide have occasionally been uncovered by erosion, in solfatara fields (e. g., Mendeleyev Volcano). S. I. Naboko believes that a precipitation of iron sulfide takes place when descending iron sulfate solutions meet ascending solutions carrying sulfide ions. An immense amount of metals leached out of rocks is carried annually out to the sea. As the acid streams meet the sea water, a considerable portion of dissolved material is precipitated and deposited as a future cement for volcanic-sedimentary material.

Volcanic energy, constantly expended in solfatara activity, is comparatively rarely used up in the paroxysms of volcanic eruptions. Major eruptions in the Kuriles have occurred in historic times, at the rate of one in several decades; the minor ones, every few years. Six comparatively minor eruptions have occurred since 1946 (Table 3).

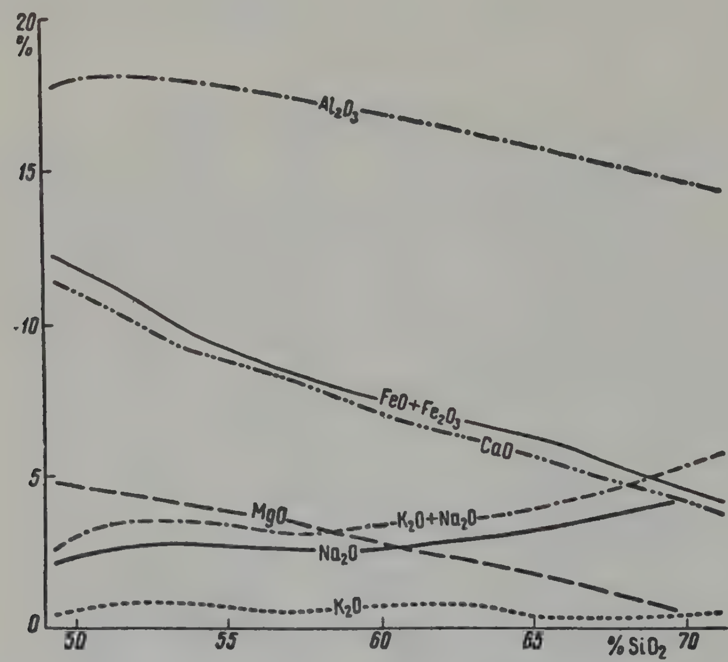


FIGURE 1. Variation diagram of the composition of recent volcanic rocks in the Kuriles.

4. A BRIEF GENERAL DESCRIPTION OF VOLCANIC ROCKS IN THE KURILES

Present among the cenotype volcanic rocks in the Kuriles are quite diversified members of the alkaline earth series, from basalts to rhyodacites; however, andesites are in the ascendence, with frequent deviations toward andesite-basalt and andesite-cadite.[3] This assemblage of genetically related rocks has certain typical common features, as follows:

1. Plagioclase is the principal mineral in incrustations and microlites, in all rocks, from the most basic to the most acid. Its incrustations are generally basic, as basic as labradorite, even in such acid rocks as andesite-dacite and rhyodacite.

2. Pyroxene predominates among the dark minerals, in all petrographic varieties, including the most acid. The only exception are some basalts where olivine is the principal dark mineral.

3. Monoclinic and rhombic pyroxenes usually occur together; with olivine in basic rocks (and occasionally in the acid).

4. The usually high content of incrustations (except in the most acid and most basic rocks).

5. A relatively acid composition of volcanic glass, which determines the presence of quartz,

---

[3]F. Yu. Loewinson-Lessing's criteria were used in differentiating the rock families.

Characteristics of the principal types of Kurile lavas are given in Table 4. Andesite-basalt and andesite are the most common.

Plagioclase is "high-temperature" in all lavas studied. The basicity of lavas strongly affects the composition of plagioclase microlites (No. 27 in the most acid, with No. 82 in the most basic of the samples analyzed) and volcanic glasses (n = 1.488 in the most acid lavas; n = 1.551, in the most basic). The basicity of its optic angle ranges from -82 to -88°. The content of fayalite, ranging from 20 to 30%, corresponds to these values. The average value of 2V is 54° for incrustations of monoclinic pyroxene, and 51° for microlites. According to M. M. Veselovskaya's diagram, these values correspond to the following compositions: 44 En, 38 Fs, 38 Wo; and 47 En, 22 Fs, 31 Wo. The optic angle for rhombic pyroxenes in the lavas analyzed ranges from -58° to -70°. According to the Winchell diagram, these angles

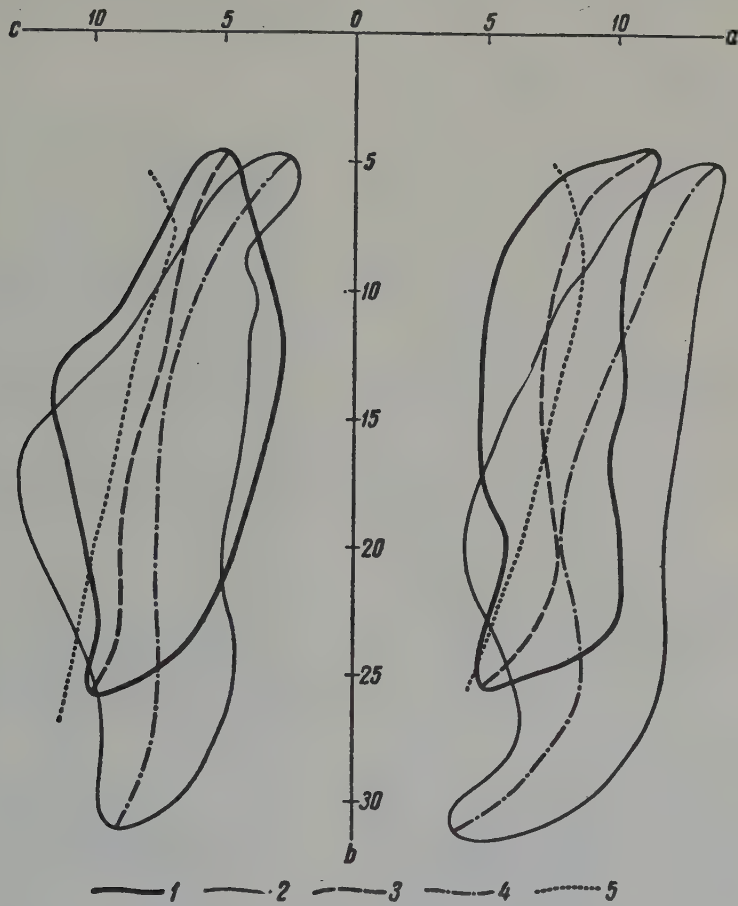


FIGURE 2. Correlation of chemical composition of associaions of volcanic rocks in the Kuriles, Kamchatka, and Japan; from A.N. Zavaritskiy's diagram

1 - outline of the field of A.N. Zavaritskiy's main numerical characteristics for volcanic rocks in the Kuriles; 2 - same for Kamchatka; 3 - median line for the cluster of A.N. Zavaritskiy's main numerical characteristics for the Kurile volcanics; 4 - same for Kamchatka; 5 - same for Japan.

plagioclase phenocrysts rises in the more basic lavas also (No. 37 in the most acid; No. 90 in the most basic). No regular changes in the properties of dark minerals have been observed in the transition from basic to acid lavas. Olivine is characterized by its reaction fringes; correspond to a 32 to 44% ferrosilite content. The difference in the chemical composition of lavas is determined by differences in the crystal-glass ratio, and that of the crystals of different minerals to assorted microlites and to plagioclase inclusions. The SiO_2 content in lavas

ranges from 50% (basalt) to 74% (rhyodacite). The R. Harker curve for a decrease in the total iron oxide content with an increase in SiO_2 is almost a straight line. The same is true for the calcium oxide. The decrease in the MgO content proceeds along a flatter curve (Figure 1). Because of the low content of alkali in all lavas, Harker's curves for CaO and Na_2O + K_2O intersect only at 68 SiO_2. This value, known as the alkaline earth index, is higher than for Japanese lavas (65%) which are supposed to be the most calcareous. In their chemistry, recent volcanics from the Kuriles are most like the recent lavas of Japan, differing from them in having an even lower alkali content in rocks of intermediate composition (Figure 2). The main features of the chemistry of Kurile lavas are as follows:

1. A distinct alkaline earth nature of all lavas, from basalt to rhyodacite.

2. The presence of free silica even in basic lavas, brought about by the low alkali content.

The Kurile lavas are derivatives of basalt magma which has assimilated, on its upward migration, some sialic material. This is substantiated by the following facts:

1. The presence of a sial root underneath the Kuriles, as established by geophysical study.

2. The volume distribution of rock types. As noted before, basic andesite and andesite-basalt are in the ascendance, with basalt and dacite quite rare. Significantly, even the basalts have a higher SiO_2 content, while olivine shows reaction fringes in the basalts.

3. The peculiarity in the chemical composition of lavas mentioned above.

T. Barth [1] points out that Peacock's alkaline earth index is an indication of the degree of contamination of magma, by sialic material. The higher the index, the higher the degree of contamination. The alkaline earth index for the Kuriles is probably the highest in the world. A. Rittman [6] has proposed recently a certain function of the chemical composition

$$S \left[S = \frac{(Na_2O + K_2O)}{SiO_2 - 43} \right]^2,$$

which gives an idea of the origin of the extrusive rock series; the oxides are taken in percent by weight; and the decrease of the function from femic to sialic rocks shows the importance of the assimilation of acid material by a basic magma. For the Kuriles, this function drops from 2. 3 to 0. 4, which indicates a contaminated magma.

REFERENCES

1. Bart, T., Teoreticheskaya petrologiya. [THEORETICAL PETROLOGY]: Izd-vo in. lit., 1956.

2. Gorshkov, G. S., Katalog deystvuyushchikh vulkanov Kuril'skikh ostrovov. [CATALOG OF ACTIVE KURILE VOLCANOES]: Byul. Vulkanolog. stantsii, no. 25, 1957.

3. Markhinin, Ye. K., K istorii razvitiya vulkanizma na Kuril'skikh ostrovakh. [CONTRIBUTION TO THE HISTORY OF VOLCANISM IN THE KURILES]: Doklady, Akad. Nauk SSSR, t. 118, no. 2, 1958.

4. Markhinin, Ye. K., Vulkany ostrova Kunashir. [VOLCANOES OF KUNASHIR ISLAND]: Tr. Laborat. vulkanolog. vyp. 17, 1959.

5. Minato, M., K. Yagi, and M. Hunanashi, Geotectonic synthesis of the Green Tuff Regions in Japan. Bull. Earthquake Rev. Inst., vol. 34, Pt 3, 1956.

6. Rittmann, A., Determination of a serial index of volcanic rocks. Bull. Volcanolog., Napoli, 1958.

Volcanological Station,
Academy of Sciences, U. S. S. R.,
Kluchi, Kamchatka

Received, 16 November 1959

NEW DATA ON THE STRUCTURE OF SOUTHERN KAMCHATKA, FROM GEOLOGIC AND ELECTROMAGNETIC STUDIES[1]

by

V. I. Tikhonov, and L. A. Rivosh

Kamchatka Peninsula is the peripheral segment of a young geosyncline located between the Mesozoic folded province of northwestern Asia and the Pacific. Its structures, especially in the eastern part, are still tectonically active.

Most of the earlier students of Kamchatka, A. N. Zavaritskiy, B. F. D'yakov, M. F. Dvali, G. M. Vlasov [2, 4, 5, 6], conceived it as a system of folded structures trending with the peninsula and continuing along the Kurile island arc. These structures have maintained their trend throughout geologic history.

Recent geologic, exploration, and geophysical studies have provided an immense amount of data differing to a considerable extent with this conventional concept of the tectonics of Kamchatka. Two principal trends of folding were established for its southern half: meridional to southeasterly, in the lower structural stages (pre-Mesozoic ?, Mesozoic, and Tertiary); and northeasterly (superimposed Pliocene-Quaternary). A correlation of geologic and aeromagnetic data refines and corroborates this concept.

Present in the lower structural stages, in basins of the Bystraya, Plotnikova, and Avacha rivers, are three folded structures: the Ganal-Khangar and the Stepanov anticlines, with the Nachikin synclinal graben separating them.

The Stepanov anticline is located largely within the Sredinnyy range. Its axis is traceable on a submeridional trend from the middle course of the Kolpakova River, south of the mouth of the Stepanova River, a right tributary of the Bystraya; farther south, the axis veers smoothly to the south-southeast, and plunges in that direction, in the upper courses of the Bannaya and the Karymchin. This fold is about 180 km long, with a maximum width of 50 km.

The Ganal-Khangar anticline lies east of the Stepanov anticline. Its northern segment falls within the northern part of the Sredinnyy Range, with its southern segment in the Ganal Range. It is about 270 to 280 km long, with a maximum width of 30 to 40 km. This fold is traceable from the upper course of the Icha, on an almost meridional trend, as far south as the Ganal Range where it veers northeast and plunges toward Petropavlovsk.

The axial parts of both anticlines are made up of pre-Mesozoic metamorphics, with limbs of Cretaceous tuffaceous siliceous rocks.

Separating the southern segments of these anticlines is the Nachikin synclinal trough, plunging southeast and filled up with Tertiary sediments and volcanics. Its known part is 100 to 110 km long and 40 km wide.

The limbs of all structures are complicated by faults which were the loci of vigorous Tertiary volcanic activity, with the resulting accumulation of considerable thicknesses of andesite and andesite-basalt.

Geologic maps (M. F. Dvali, G. M. Vlasov and B. A. Yarmolyuk, V. P. Mokrousov, etc.) show several smaller folds of the same trend, north of these structures. A synclinal trough of the same trend is present in the Nalycheva River basin, northeast of the Ganal-Khangar anticline; it is filled with Tertiary deposits. It is at least 130 km long, with an apparent thickness of 25 to 30 km. An anticlinal fold of the Nalycheva trough trend is quite conspicuous in the Shipunsk Peninsula; its core is Cretaceous; it is 40 km long and not over 15 km wide.

Judging from the distribution of Tertiary deposits, there should be, farther northeast, a large southeasterly trending trough; its synclinal nature is best expressed within the southeastern slope of the Valaginsk Range, in the middle course of Zhupanova River. Present here is a well-defined south-southeasterly trending fold whose core is Upper Miocene or Pliocene, and the limbs, Lower and Middle Miocene. Its segment not covered by Quaternary andesite-basalt is 40 km long and 25 km wide.

---

[1]Novyye dannyye o tektonicheskom stroyenii Yuzhnoy Kamchatki (po rezul'tatam geologicheskikh i aeromagnitnykh rabot). pp. 59-67.

The northern terminal of the Valaginsk Range is a minor anticline associated with the above-named syncline. Cretaceous rocks are exposed in its core, with Tertiary in the limbs. This structure is overlain in the southeast by Quaternary extrusives; it appears to trend south-southeast from the Shipunsk Peninsula, and north of there.

The present poor state of knowledge precludes any judgement of the trend of lower stages in these structures, in the northern part of the Sredinnyy Range and in the Tumrok and Kumroch ranges. The data on hand suggest a similar arrangement of structures, except for their trend, which appears to approach meridional, judging from the Tyushevsk trough.

Much better expressed in Kamchatka is the younger superimposed Kurile trend. It is manifested in the relief as well as in the flexing of peneplanation surfaces and of lava flows; in the change of the nature and height of terraces; in the distinct zones of younger faults; and in Quaternary volcanism.

The northeasterly trending Sredinnyy and East Kamchatka ranges (the latter differentiated into the Ganal, Valanginsk, Tumrok, and Kumroch Ranges) undoubtedly are young anticlinal structures having originated largely in the Pliocene. Their limbs, as well as the Quaternary andesite-basalt flows, are cut by faults parallel to the deep Kurile-Kamchatka trough. The elevations of lava flows and the peneplain surfaces are considerably higher in the crestal parts of these uplifts, becoming progressively lower in their sides, as can be seen clearly along a stretch from the Kronotskiy Peninsula to the Tumrok Range; also in the Kumroch Range, of Azhabach'ye Lake.

In a number of places, rivers: crossing the Kurile trend ranges are fringed with low and wide constructional terraces; toward the crests of the ranges, the latter change gradually to high and narrow basement rock terraces with a thin alluvium cover.

The Central Valley of Kamchatka is a major young trough filled with unconsolidated and volcanic Quaternary deposits. It separates the Sredinnyy and east Kamchatka ranges. Its wings are complicated by major northeasterly faults. In the south, this trough becomes a narrow graben cutting the lower stage structures, as is especially conspicuous between the villages of Pushchino and Apacha. Associated as a rule with the limbs of these major recent structures are zones of the most vigorous Quaternary volcanism.

All this is evidence of tectonic activity in structural zones with the Kurile trend, continuing into the present. Many geologic features of Kamchatka are reflected in magnetic maps.

Before going into an interpretation of aeromagnetic data, it is expedient to pause briefly for the principal geologic causes of magnetic anomalies, in this region.

1. A peculiar feature of the geologic structure of the entire peninsula is the wide development of volcanic facies against the general background of terrigenous and areno-argillaceous deposits. Flows of intermediate to basic extrusives were of an areal magnitude, largely in the Late Cretaceous, Paleogene and Early Quaternary. The major extrusive sheets and sills, responsible for the vast positive magnetic fields were formed then. Here, the areas of intensive linear magnetic anomalies reflect the feeding channels and roots of the flows (where such areas are not obviously associated with the still younger volcanic relief features).

Such magnetic fields are present in areas of the Nachikin, Nalycheva, Shipunsk-Karganins, and Tyushevsk troughs; in the southern and southeastern parts of the Central Kamchatka trough; and in the offshore segments of the oceanic bottom (Figure 1).

Thus, different geologic structures may have similar magnetic characteristics. Accordingly, a single interpretation of aeromagnetic data for the entire region is impossible apart from geologic considerations.

The presence of two structural zones is also corroborated by the distribution of the magnetic anomaly zones (Figure 1). The large extrusive sheets, whose distribution is related to the elongated tectonic zones, are represented as vast linear disturbances in the positive magnetic field, standing out sharply against the relatively inconspicuous negative magnetic fields reflecting normal nonmagnetic sedimentary rocks or ancient metamorphic bodies.

2. Magnetic fields rapidly changing their signs are associated with Pliocene to Early Quaternary plateau basalts constituting the "armor" of considerable areas in Kamchatka (e. g., in the southern volcanic province).

3. Narrow linear magnetic anomalies are associated with fault zones or with other weakened crustal belts favorable for the passage of magmatic melts.

4. The boundaries of sharply differing magnetic fields mark in many places the northwesterly, latitudinal, and northeasterly normal faults controlling the relative vertical movements of adjacent magnetic rock blocks. These zones, local according to electromagnetic data, may have a considerable length, being related to both the young and old structural plans.

5. The distinctive isolated isomatric anomalies mark the young postglacial conic volcanic

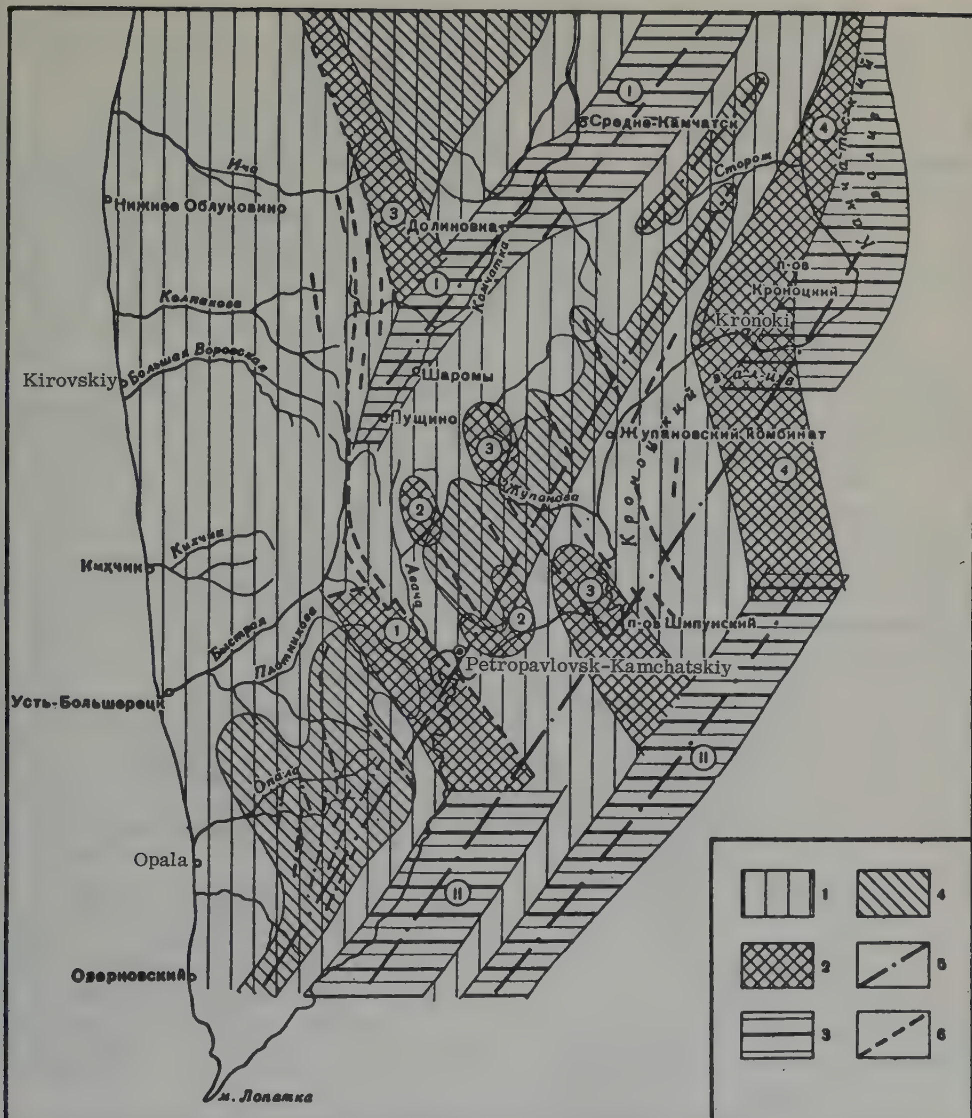


FIGURE 1. Distribution of magnetic anomalies. Tectonic elements are marked off from aeromagnetic data.

1 - areas of largely uniform and weak negative magnetism; 2 - areas of disturbed positive magnetism related largely to Tertiary volcanics (Numerals on map: 1 - Nachikin trough; 2 - Nal'chevo trough; 3 - Shipunsk-Kirganinsk zone; 4 - Tyushevsk trough); 3 - areas of disturbed positive magnetism associated largely with Quaternary extrusives: I - southern and southeastern parts of the Central Kamchatka trough, II - folds and faults of the Kurile trend; 4 - areas of disturbed, largely sign-changing magnetism, related to superimposed belts of Quaternary volcanism; 5 - major faults with the Kurile trends, controlling the distribution of zones of young volcanism; 6 - faults associated with the ancient folding plan.

tructures and eruption centers of ancient, almost completely destoyed volcanic cones.

Ancient shield-like volcanoes, their relief roken by glaciers, are marked by rapid changes in the sign of their magnetism (Bol'shaya Ipel'ka) or by intensive saw-tooth shaped magnetic fields (Zhupanovskiye Vostryaki, Schmidt).

6. Basic and ultrabasic intrusive bodies are

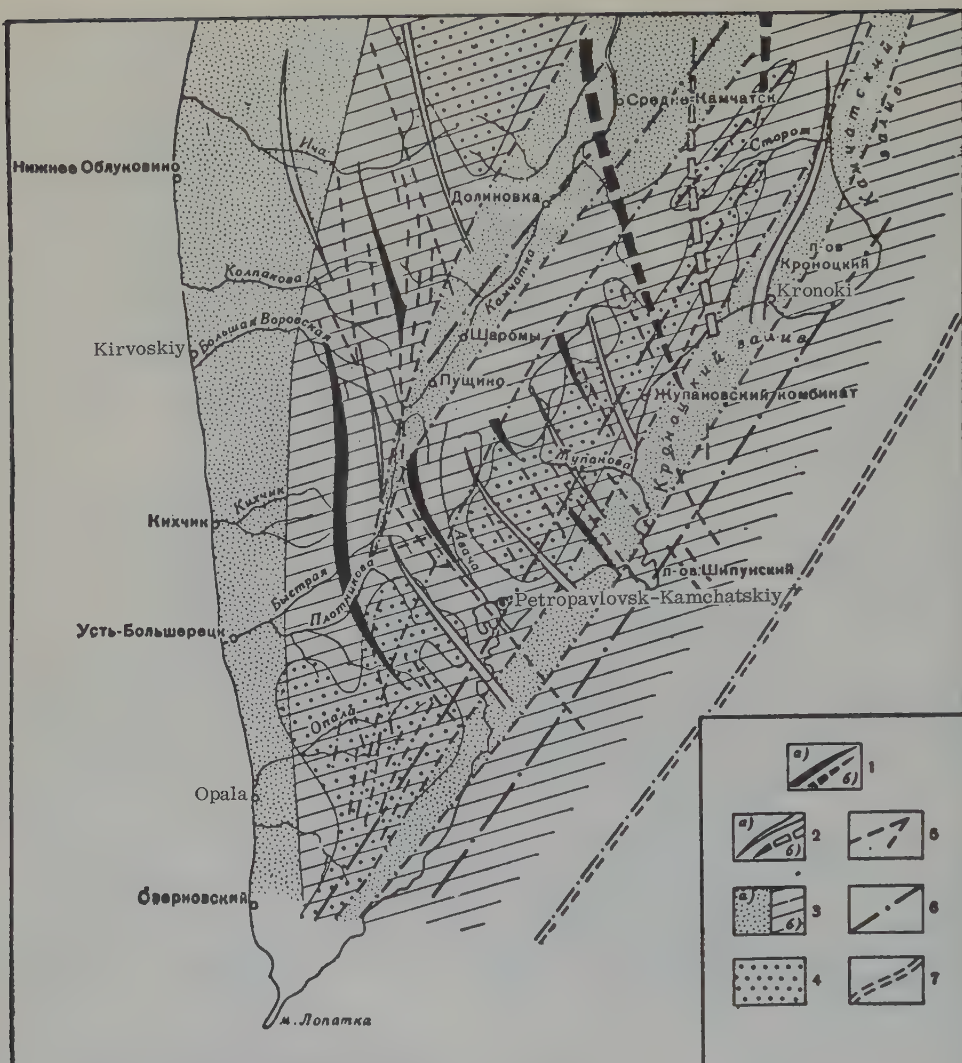


FIGURE 2. Main tectonic features of southern Kamchatka (from geologic and electromagnetic data).

Pre-Mesozoic, Mesozoic, and Tertiary structural stages: 1 - anticlinal axes; 2 - synclinal axes: a - known, b - assumed; 3 - province of young superimposed uplifts and troughs (Kurile trend); 4 - superimposed Quaternary volcanic belts; 5 - faults associated with the ancient folding plan; 6 - faults of the Kurile trend, controlling the distribution of young volcanic zones and associated with the young structural plan; 7 - tectonic escarpment in front of the Kurile-Kamchatka trough.

reflected in isometric magnetic anomalies, differing from the volcanic structures in their lack of high negative values of ΔT in the north side of the anomaly, and in a more broken up aspect of the field.

All these types of magnetic anomalies are conspicuous in the area under study; it should be stressed, however, that the most essential among them, those that determine the general aspect of the magnetic field are the vast positive magnetic fields reflecting the two structural plans of Kamchatka (Figure 2).

The Nachikin trough is the best reflected on the magnetic map. Its higher magnetic values reflect the thick extrusive bodies emplaced in a structure which subsequently acquired the features of a graben bound by long faults, in the southwest and northeast. These faults are well

xpressed by both geologic and aeromagnetic ata, along its northeastern boundary.

An abrupt change in the magnetic field suggests the presence of similar faults along the orthwestern boundary of the graben, as well. resent in the northern segment of this strucure are two correlative, linear, elongated zones f magnetic anomalies, evidently marking the eeder tectonic zones. In the southern part of ne graben, such zones are concealed under)uaternary basalt flows and northeasterly rending young volcanic ranges; however, the eneral northwesterly trend of the trough is onspicuous on the magnetic map, present under ne young volcanics. In other areas (e. g., near Coryaki), the Quaternary lavas, because of neir slight thickness, are not at all reflected in he magnetic map.

Only the relatively undisturbed, weak negative nagnetic field marks the anticlinal structures ringing the trough; this becomes anomalous nly southwest of the graben in the Stepanov nticline area because of Quaternary structures uperimposed on ancient structures.

Present here as well as in the Ganal Range reas are elongated northwesterly zones of nagnetic anomalies enhancing the general strucural trend. These mark the intrusions and solated volcanic structures associated with ncient faults along the junctions of uplifts and ubsidences, and rejuvenated by younger tec-onic movements.

The amazing coincidence of a positive magnetic field with the entire Nachikin trough is of mportance. It appears that, as this structure leveloped, it was filled up with extrusive rocks vhich entered it along zones of weakness de-reloped simultaneously with its formation, ılong its periphery and in the maximum zone of subsidence.

Aeromagnetic data as well as data obtained n oceanographic studies by S. S. Vityaz, of the)ceanology Institute, Academy of Sciences, J. S. S. R. [8], suggest a southeasterly con-inuation of this structure toward the Kurile-Kamchatka trough. This feature is expressed n the magnetic map as well as in the adjacent ottom relief. The aeromagnetic data definitely ndicate another major tectonic zone, the Shipunsk-Kirganik, traceable across a positive nagnetic field in the middle Zhupanova course, he Shipunsk Cape area. This zone is traceable over most of its length at the junction of ancient uplifts and subsidences. The discontinuous nature of this magnetic anomaly is associated most probably with undulations in the hinge line of an ancient structure or with a change in facies which apparently is not everywhere represented by volcanics.

The northwesterly structural trend in the Shipunsk Cape has been established by geologic observations, as well (V. P. Mokrousov, 1958). It is enhanced by the series of linear elongated magnetic zones, north and northeast of Shipunsk Cape, and by a number of volcanoes along the structural flanks (such as the Zhupanovsk-Dzenzur). Here, as in the Nachikin trough, volcanic structures are arranged in chains along ancient fault zones. The Nalycheva trough, adjacent in the northeast to the Ganal anticline, is expressed by two positive magnetic zones. A magnetic map of all these negative structures clearly shows the ancient northeasterly trend of folding.

The somewhat different trend of the Tyushevsk trough indicates that Upper Cretaceous and Tertiary structures of Kamchatka have a nearly meridional trend in addition to the northwesterly.

The younger northeasterly structural trend is clearly reflected in major positive magnetic zones extending along the Central Kamchatka trough and in off-shore reaches of the ocean bottom along the northwestern slope of the Kurile-Kamchatka trough. These zones mark major faults of the Kurile trend, which control the distribution of young volcanic belts. The two southern anomalous zones coincide with submarine tectonic escarpments in the western slope of the Kurile-Kamchatka trough, as determined by oceanographic studies of the Vityaz.

Fault zones along the flanks of the Central Kamchatka trough and in its southern reaches have also been the result of the same young tectonic movements which have strongly affected the Kurile-Kamchatka trough region. In the peninsula, these movements have resulted in a series of superimposed northeasterly uplifts and troughs [7]. The northeasterly faults were loci of vigorous volcanism, contemporaneous with the formation of the Central Kamchatka graben and leading to the appearance of vast basic extrusive flows which are reflected in the map as broad, linear, extended positive magnetic zones.

The major fault zones are symmetric with relation to the young mountain system of Valaginsk, Tumrok, and Kumroch Ranges, formed in Quaternary orogenies; they appear to fringe this system, arranged around its periphery.

An anomaly zone west of this system and consisting of two en echelon magnetic fields, bends at latitude 55° 10' and duplicates the trend of the younger ranges. Its bend is located near the boundary between the Valaginsk and Tumrok horst ranges, which does not appear to be an accident. Obviously, following the formation of the northeasterly trending ranges, there was renewed movement along the ancient northwesterly faults. These movements displaced individual blocks in both the younger mountain system and

in the adjacent areas of the Central Kamchatka trough; consequently, the anomaly zone has assumed its en echelon arrangement and a different aspect of its northern and southern magnetic fields.

The eastern volcanic province, trending in a broad belt along the east coast of Kamchatka, has different magnetic characteristics in its different areas. On the whole, this entire volcanic belt is marked by a disturbed sign-changing magnetic field which becomes more regular at latitude 54° 10', where distinct local anomalies mark the individual volcanic structures (Sopkas Kronotskaya, Krasheninnikov, Tauschnitz, Zubchataya, etc.) while linear anomalies mark the long faults which served as feeders for magma flows.

One such fault is particulary conspicuous southeast of the Tumrok Range, where it is marked by the Gamchen series of volcanoes (Konechnaya, Vysokaya, Gamchen, Schmidt, etc.). Northeast from the southern volcanic province toward Mt. Konechnaya, there is a general narrowing of the magnetic anomaly, related to the heterogeneous structure of extrusives in the eastern volcanic zone, which is expressed mostly in different thicknesses and areal extent of the lava flows. The thickest lavas are concentrated in the southern volcanic province where the magnetic anomalies mark the flows proper as well as their roots, while the more intensive magnetic fields to the northeast are caused mostly by individual volcanic structures and faults associated with the extrusive activity. The flows themselves, because of their smaller thickness, here, do not produce magnetic anomalies measurable at 200 to 300 m above.

Such a picture of the magnetic field may mean a slackened volcanic activity of the shield volcanoes, from southwest to northeast, inasmuch as these very volcanoes formed the thick basalt lava flows in Kamchatka. The younger stratovolcanoes, developed in lava plateaus and in the calderas of ancient volcanoes, form large surface cones reflected in local magnetic anomalies, approaching isometric, rather than the extensive sign-changing magnetic fields of the southern volcanic zone, and almost entirely missing in more northerly areas of the eastern volcanic zone.

A few words on the nature of the magnetic field in marginal parts of the Sredinnyy Range. The boundary between the ancient block and its fringe of younger folded structures is not expressed in the magnetic map, in the west; in contrast, it is particularly well expressed in the east, by a series of linear magnetic anomalies which mark the longitudinal and transverse normal faults. While only isolated areas of disturbed magnetism, associated with small and thin Quaternary extrusive flows, are present in the west, near the anticlinal structure boundary, the anomalous ΔT zones in the east are quite distinct. Associated with these areas were the Upper Cretaceous - Paleogene volcanic phenomena localized along the extended tectonic zones.

The aeromagnetic data suggest a relatively gentle plunge of ancient metamorphics toward the Sea of Okhotsk, under the younger Tertiary deposits in the West Kamchatka trough.

Having set forth the principal results of geologic and aeromagnetic studies, the authors deem it advisable to state that their goal was not an exhausive description of the tectonic structure of this region but rather its main features and the close relationship between the geologic structure and its magnetic field. This is the first attempt at correlating the geologic and aeromagnetic data for Kamchatka. As such, it leaves many points as yet obscure.

REFERENCES

1. Vlasov, G. M., Novyye dannyye po geologii Kamchatki i perspektivy yeye rudonostnosti. [NEW DATA ON THE GEOLOGY OF KAMCHATKA AND ITS ORE PROSPECTS]: Sov. geologiya, no. 5, 1958.

2. Vlasov, G. M., Priokhotskiye skladchatyye oblasti. [FOLDED PROVINCES ADJACENT TO THE SEA OF OKHOTSK]: In the book, "Geologicheskoye stroyeniye SSSR", t. 3, Izd-vo Akad. Nauk SSSR, 1958.

3. Vyalov, O. S., Skhema tektonicheskogo podrazdeleniya Kamchatki. [TECTONIC DIFFERENTIATION OF KAMCHATKA]: Doklady, Akad. Nauk SSSR, no. 6, 1952.

4. Dvali, M. F., Geologicheskoye stroyeniye i neftenosnost' Vostochnoy Kamchatki. [GEOLOGIC STRUCTURE AND OIL IN EASTERN KAMCHATKA]: Gostoptekhizdat, 1955.

5. D'yakonov, V. F., Geologicheskoye stroyeniye i neftenosnost' Zapadnoy Kamchatki. [GEOLOGIC STRUCTURE AND OIL IN WESTERN KAMCHATKA]: Gostoptekhizdat, 1955.

6. Zavaritskiy, A. N., Vulkany Kamchatki. [VOLCANOES OF KAMCHATKA]: Tr. Labor. vulkanolog. Akad. Nauk SSSR, vyp. 10, 1955.

7. Tikhonov, V. I., Skhema tektoniki yuzhnoy chasti poluostrova Kamchatki. [TECTONIC SCHEME OF SOUTHERN KAMCHATKA]: Doklady, Akad. Nauk SSSR, t. 127, no. 1, 1959.

Udintsev, G. B., Rel'yef Kurilo-Kamchatskoy vpadiny. [RELIEF IN THE KURILE-KAMCHATKA TROUGH]: Tr. In-ta okeanologii, t. 12, 1955.

Geological Institute, Academy of Sciences, U. S. S. R., Moscow

Received, 22 February 1960

GRANITIZATION OF METABASICS AND ROCKS OF THE LOWER FORMATION FROM THE INGULETS AREA, KRIVOY ROG[1]

by

A. I. Strygin, and M. N. Dovgan

N. P. Semenenko [11] and Yu. Ir. Polovinkina [8] differentiate two complexes of granites developed along the Krivoy Rog iron basin: the Kirovgrad-Zhitomir and Dnepropetrovsk-Tokva. They assign to the first the Saksagan plagiogranite developed along the eastern boundary of the Krivoy Rog series. These granites usually contact the metabasics and less commonly the Lower Formation rocks; their relationship with these two groups is still subject to argument.

N. P. Semenenko [10] and A. P. Nikol'skiy [5, 6] assign a Krivoy Rog and post-Krivoy Rog age to the Saksagan plagiogranites, respectively. N. P. Semenenko's reason is the common trend of the Krivoy Rog folding and the granite structures. A. P. Nikol'skiy [5, 6] infers a post-Krivoy Rog age of the plagiogranite on the basis of his study of their relations to amphibolites and metasandstones from the Lower Formation, in the Mudrenaya station area and in the Privorotnaya ravine.

Other students, Ya. N. Belevtsev [1], Yu. Ir. Polovinkina [8, 9], and M. P. Kulishov [3], believe that the Saksagan plagiogranites are pre-Krivoy Rog; they cite the lack of conformity between the trend of granite structures and the strike of Krivoy Rog beds and the lack of the effect of granites on metamorphic rocks. The pre-Krivoy Rog age of plagiogranites was substantiated by the finding of pebbles of presumably Saksagan granites in the Lower Formation conglomerates.

A number of deep tests were drilled in recent years at the plagiogranite — Krivoy Rog contact, in the Ingulets area (southern part of the Krivoy Rog iron-ore basin); they encountered numerous remnants of metabasics and Lower Formation rocks, in plagiogranites (Figure 1). These xenoliths vary in size, from test to test, from 0.1 m to 15 m across.

Participating in the structure of the Ingulets area are plagiogranites, migmatites, and rocks of the Krivoy Rog series and the metabasic sequence. A detailed description of its geology is found in Ye. N. Yakovlev's work [1].

The Krivoy Rog series of the Ingulets area make up a narrow and steep Likhmanovka syncline whose west limb is cut off by the Likhmanovka thrust (Figure 1); the strike changes from submeridional to northeasterly and northwesterly.

These rocks are underlain by metabasics represented by amphibolites, commonly biotitic and feldspatic. The metabasics range in thickness, along the strike, from 800 m (the Rakhmanovo village area) down to 100 m (closure of the Likhmanovka syncline); they are missing in the Ingulets mine area, except for small remnants in plagiogranite.

As everywhere in the Krivoy Rog basin, metabasics are overlain here by the Lower Formation of the Krivoy Rog series. This formation is 400 to 600 m thick, in the north (closure of the Saksagan synclinorium) and 24 to 40 m in the Ingulets mine area.

The Likhmanovka syncline rocks contact gray plagiogranite in the east, and assorted migmatites in the west, along the Likhmanovka thrust.

Externally, the plagiogranites are gray, massive, fine-grained, and hypidiomorphic (Figure 2). In some segments, they show a more or less conspicuous linear arrangement of biotite and quartz. Their average mineral composition is as follows (in %): plagioclase (No. 20-25), 55 to 60; quartz 25 to 30; biotite, 10 to 15; secondary minerals: chlorite, epidote, muscovite, calcite, sulfides, not over 4%, for the total; accessory minerals present are zircon, apatite, and ilmenite, a total of about 1%. Microcline is not uncommon, usually associated with micro- and macrofractures.

Plagioclase is present in relatively coarse idiomorphic tablets and in fine isometric grains; the latter, like microcline, occur in fractures and are somewhat younger than the tablets.

---

[1]Granitizatsiya metabazitov i porod nizhney svity v inguletskom rayone krivorozh'ya, pp. 68-78.

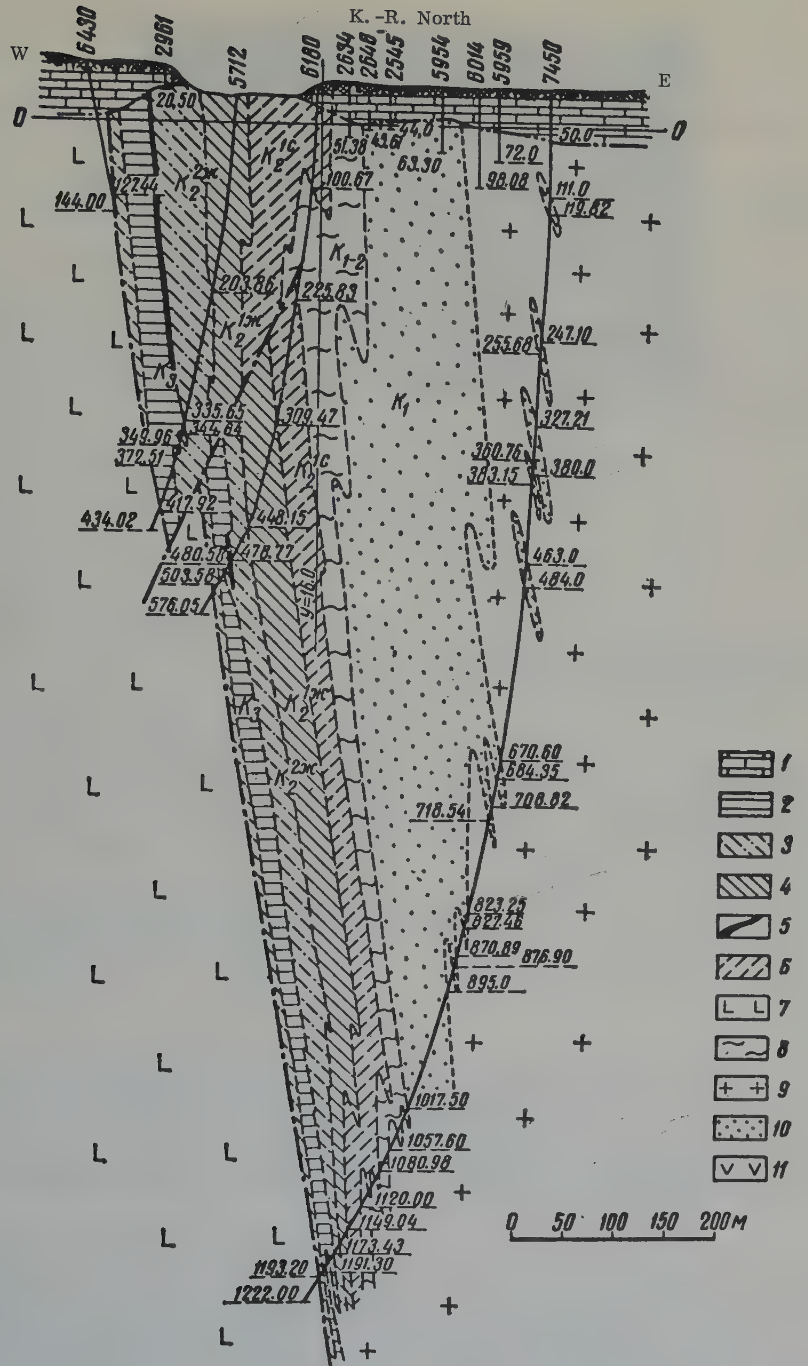


FIGURE 1. Cross-section of the Krivoy Rog series in the Likhmanovka syncline Shown in Test No. 7450 are some of the largest remnants of metabasics and rocks of the Lower Formation, in plagioclase.

1 - Cenozoic deposits; 2 - shales of the upper formation, Krivoy Rog series; 3 - cummingtonite-magnetite hornfels; 4 - biotite-cummingtonite-magnetite hornfels; 5 - hematite-martite and magnetite rocks; 6 - biotite-cummingtonite schists; 7 - migmatite; 8 - the talc horizon rocks; 9 - plagiogranite; 10 - quartzite and schist of Lower Formation, Krivoy Rog series; 11 - amphibolite (remnants in granite).

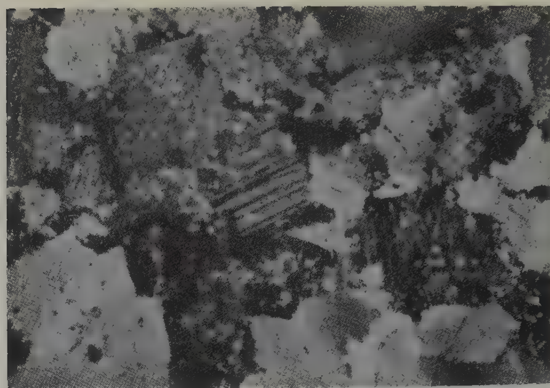


FIGURE 2. Hypidiomorphogranular plagiogranite

Thin section, 20 X, Nicols crossed.

Quartz and biotite form more or less coarse accumulations among the plagioclase bodies. The refractive indices for biotite, determined by the immersion method for β, range from 1.633 to 1.640.

In mineral composition, accessory minerals, textural and structural features, and occurrence, the Ingulets plagiogranite is correlative with the Saksagan granite. A comparison of chemical analyses (Table 1), numerical characteristics (Table 2), and the composition projection diagram (Figure 3) for the two, also suggests their similarity. The main feature of the two granites is their lower silica content and a higher content of titanium, iron, and alkaline earth minerals.

As mentioned before, the granites carry remnants of rocks from the Lower Formation and the metabasic complex which have fairly sharp contacts and irregular in-and-out outlines. At its contact with metabasic inclusions the granite is enriched in biotite and ilmenite and in places carries xenomorphic hornblende crystals.

The metabasic remnants are represented by hornblendic, less commonly actinolitic varieties of amphibolite (Figure 4), showing various degress of schistosity. At the granite contact, the amphibolites are commonly feldspathic and altered to plagioclase-biotite schist.

In their structure and texture, as well as in mineral composition, amphibolite remnants in granite are similar to amphibolites underlying the Lower Krivoy Rog formation. This similarity is corroborated by their chemical analyses (Table 3) and numerical characteristics (Table 4), as compared with A. N. Zavaritskiy's diagram of the compositions projection (Figure 3).

The absence of the metabasics in the Ingulets mine, except for their altered remnants in granite, suggests that the metabasic complex has been replaced here by granite; this may explain the above-mentioned peculiarity in the chemical composition of the granite. At the Lower Formation contact, the granite locally is reminiscent of gneiss, but most frequently of "shadow" migmatite; they carry remnants of quartz-muscovite and muscovite-biotite schists, locally quartzitic. The transitions from schist to gneiss and from gneiss to granite are usually so gradual as to render it difficult to determine the true nature of the rock.

The principal minerals of the gneisses and migmatites are plagioclase, quartz, biotite, occasionally muscovite, with subordinate microcline; in places garnet, tourmaline, staurolite, andalusite; the accessory minerals are the same as in the Lower Formation.

Plagioclase is represented by oligoclase No. 20-25, locally by albite No. 5, and forms relatively large incrustations arranged along the bedding and schistosity, by replacing quartz and muscovite (Figure 5). Present along with the porphyroblastic variety is fine-grained plagioclase with isometric outlines.

Microcline occurs usually in fine-grained intergranular segregations, in microfractures, and in metasomatic formations on plagioclase. Judging from the fact that microcline and fine-grained plagioclase cut the oligoclase incrustations, they are somewhat younger than the latter, having been caused by intramineralization shifts.

Table 1

Chemical analyses of granites (by weight %)

Oxides	Granite with amphibolite remnants (analysis nos.)					Granite, migmatite, gneiss with remnants of the Lower Formation rocks (analysis nos.)					Saksagan granite[1] (analysis nos.)		
						gneiss	migmatite	migmatite	granite	granite			
	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	66.10	67.64	69.00	69.40	67.30	67.56	68.53	69.26	66.00	75.40	69.92	68.30	72,74
TiO_2	0.80	0.28	0.42	0.36	0.46	0.24	0.33	0.58	0.46	0.09	0.17	0.31	0,11
Al_2O_3	14.21	14.90	14.79	16.12	14.71	16.76	15.18	14.10	15.13	12.50	15.01	18.48	14.87
Fe_2O_3	0.64	1.65	1.40	1.02	0.14	1.46	1.51	0.70	0.35	0.70	1.64	1.63	0.11
FeO	4.91	3.73	2.83	2.74	4.65	2.58	2.58	4.13	4.39	2.20	2.01	2.43	1.72
MnO	0.05	0.05	0.04	0.06	0.07	0.04	0.06	0 05	0.08	0.02	0.06	0.05	Trace
MgO	2.60	2.21	1.90	1.08	1.88	1.90	1.94	2.30	1.73	0.65	0.72	1.09	1.41
CaO	2.35	1.77	1.65	2.56	2.60	0.42	2.31	1.00	3.30	2.05	2.80	2.84	0.70
Na_2O	4.18	4.66	4.26	4.59	5.20	3.50	4.29	4.37	4.51	5.10	4.10	2.98	5.83
K_2O	1.97	1.65	1.24	1.22	1.61	2.50	1.56	2.03	1.49	0.80	1.66	1.12	1.47
P_2O_5	0.19	0.11	0.13	—	0.19	0.11	0.11	0.10	0.12	0.04	0.06	—	0.02
CO_2	0.18	0.26	0.11	—	0.26	—	—	0.11	1.14	0.36	—	—	—
S_{total}	0.03	0.08	0.01	—	0.01	0.22	0.09	0.03	0.02	0.04	—	—	—
Losses in heating	1.40	0.74	1.57	0.96	1.41	2.45	0.99	1.52	1.48	0.42	1.32	0.70	0.97
H_2O	—	0.09	—	0.22	—	0.04	0.08	—	—	—	0.02	0.18	0.02
SO_3	—	—	—	—	—	—	0.22	—	—	—	0.12	—	0.15
All others	0.02	—	—	—	—	—	—	—	0.01	0.06	—	—	—
Σ	99.63	99.82	99.35	100.33	100.49	100.78	99.78	99.78	100.21	100.43	99.61	100.11	100.12

[1] All analyses by the Laboratory of the Ukrainian Geologic-Eploration Trust and Institute of Geol. Sciences, Academy of Sciences Ukrainian S.S.R.

[2] Analyses 11, 12, 13 are after Ya.N. Belevtsev [1].

Table 2

Numerical characteristics of granite, after A.N. Zavaritskiy

Analysis Nos.	Numerical characteristics												
	principal						supplementary						
	s	a	c	b	Q	$\frac{a}{c}$	a'	m'	f'	n	t	φ	c'
1	74.7	11.9	2.8	10.6	22.8	4.3	10.8	41.1	48.1	76.2	0.91	5.1	—
2	74.5	12.2	2.0	11.3	22.4	6.0	26.2	32.0	41.8	81.1	0.36	12.2	—
3	76.2	10.8	2.0	11.0	28.6	5.4	38.9	27.6	33.5	83.5	0.43	10.5	—
4	77.8	11.6	8.5	2.1	29.8	5.5	39.4	21.2	39.4	85.0	0.4	9.4	—
5	74.2	13.3	2.8	9.7	19.0	4.8	—	28.4	44.6	83.1	0.54	0.68	27.0
6	72.7	10.7	0.5	16.1	23.7	23.9	59.6	18.8	21.6	68.1	0.26	7.2	—
7	76.6	11.3	2.8	9.6	27.4	4.2	30.8	32.2	37.0	80.7	0.35	12.3	—
8	74.7	12.0	1.2	12.1	24.1	10.0	31.8	31.8	36.4	79.2	0.6	4.5	—
9	74.5	11.9	4.0	9.6	20.9	3.0	—	30.3	46.5	82.0	0.54	3.5	23.2
10	80.8	11.7	2.1	5.4	36.1	5.7	—	18.8	45.9	90.1	0.08	9.4	35.3
11	79.1	11.2	3.3	6.4	32.5	3.4	30.2	18.2	51.6	79.5	0.1	21.5	—
12	76.9	12.9	2.9	7.3	25.1	4.0	29.6	24.1	46.3	76.2	0.3	11.1	—
13	74.6	7.7	3.3	14.4	32.5	2.3	63.9	11.8	24.3	80.0	0.3	9.1	—

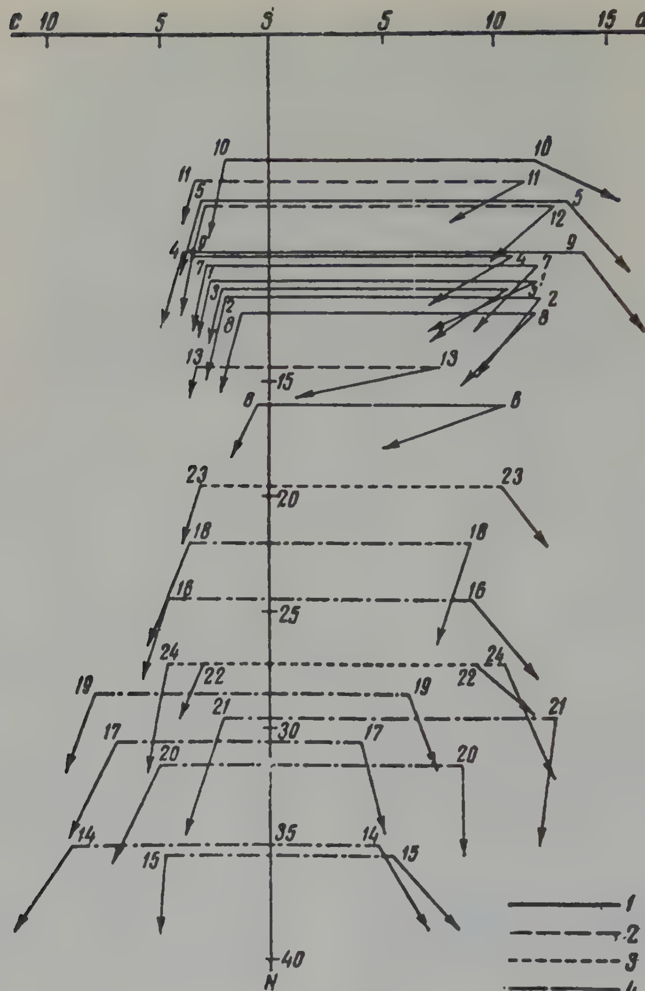


FIGURE 3. Diagrammatic projection of the composition of plagioclase amphibolites, after A.N. Zavaritskiy.

1 - analyses 1-10: granite from the marginal zone of the massif, in the Ingulets mine area; 2 - analyses 11-13: Saksagan granite; 3 - analyses 22-24: metabasics from the east limb of the Likhmanovka syncline; 4 - analyses 14-21: metabasics from remnants in granites of the Ingulets mine area.

Biotite and muscovite form either fine and broken partings or else clusters oriented with the bedding.

In both the granitized rocks and mica schists of this zone, quartz occurs in lenticular or "augen" bodies and is marked by its coarser grain. The chemical composition of these rocks corresponds to that of granite (see Table 1, analyses 6-8).

Rocks of the "shadow" migmatite and gneiss type constitute a gradual transition from granite to schist in the remnants, as well as to the Lower Formation schist and quartzite. Thus, the contact between the granite and the Lower Formation rocks, in the Ingulets mine, is not sharp, being represented by a zone of granitized rocks, several tens of meters thick.

Schist and quartzite in remnants within this zone, and those from the Lower Formation not affected by granitization, are characterized by the same mineral composition and textural and structural features, and are described together. Quartzites are rather rare in the Lower Formation of the Ingulets mine, where they occur as intercalations and layers, from 5 to 10 cm to

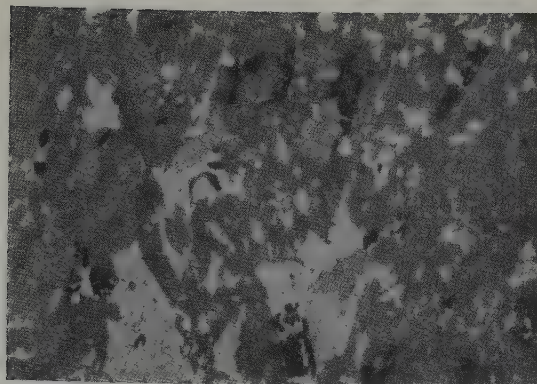


FIGURE 4. Plagioclase-hornblende metabasics with ilmenite inclusions.

Thin section, 43 X, single Nicol.

everal meters thick. In addition to quartz, ese quartzites often carry sericite and uscovite and occasional metasomatic formaons in veinlets and spots of a garnet-clinoroxene composition, with titanite and plagioase. These quartzites are granoblastic igure 6).

The principal schist minerals are quartz, muscovite, and biotite, with common staurolite, garnet, tourmaline, and amphiboles, and less common andalusite. Accessory minerals include ilmenite, zircon, sphene, apatite, and sulfides.

Quartz in schist forms thin granoblastic

Table 3

Chemical analyses of amphibolites (in % by weight)

xides	Amphibolite from remnants in granites of the Ingulets mine area								Amphibolite from the metabasic complex[1] (analysis nos.)		
	14	15	16	17	18	19	20	21	22	23	24
SiO_2	48.60	47.70	55,64	49.16	56.80	48.00	50.19	45.80	53.00	57.67	51.36
TiO_2	2.20	2.80	1.29	1.21	1.49	1.40	1.07	2.49	1.46	1.29	0.57
Al_2O_3	11.45	11.11	14.46	13.41	15.20	15.90	14.44	13.79	11.76	12.18	15.29
Fe_2O_3	3.10	5.00	2.35	3.71	0.64	3.70	3.03	7.80	5.51	3.52	1.03
FeO	14.07	13.81	8.06	13.07	8.78	11.36	13.21	13.20	11.59	9.00	7.29
MnO	0.17	0.24	0.19	0.20	0.10	0.19	0.13	0.14	—	0.15	0.19
MgO	7.40	5.63	4.90	6.89	5.85	6.00	8.63	6.79	3.38	2.60	7.96
CaO	6.25	8.25	6.35	8.02	2.85	9.00	1.95	4.30	7.91	5.42	9.48
Na_2O	1.49	2.10	3.40	1.30	3.20	1.94	1.96	2.92	3.31	3.54	4.12
K_2O	1.16	0.62	1.35	0.80	1.90	1.16	1.57	1.43	1.68	1.84	1.25
Cr_2O_3	0.01	0.04	0.01	—	0.04	0.01	—		—	—	—
V_2O_5	0.06	0.06	0.02	—	0.05	0.01	—	0.02	—	—	—
P_2O_5	0.29	0.28	0.21	0.18	0.14	—	0.11	—	—	—	—
CO_2	0.11	0.29	0.37	—	0.22	0.75	0.29	0.20	—	—	—
S total	0.76	0.17	0.11	—	0.29	—	—	—	—	—	—
sses in eating	1.23	0.91	1.56	2.01	2.22	1.06	3.83	1.28	0.93	0.74	1.44
H_2O	—	—	—	0.04	—	—	0.14	—	—	1.87	0.18
SO_3	1.90	—	—	0.49	—	—	0.25	—	—	—	—
Σ	100.24	100.01	100.87	100.49	99.77	100.18	100.80	100.16	100.53	99.82	100.16

[1] Analyses 22, 23, and 24, after I.S. Usenko [12]

Table 4

Numerical characteristics of metabasics, after A. N. Zavaritskiy

Analysis Nos.	Numerical characteristics												
	principal						supplementary						
	s	a	c	b	Q	$\frac{a}{c}$	a'	m'	f'	n	t	φ	c'
14	55.2	4.8	5.0	35.0	—4 2	0.96	—	34.5	44.7	65.8	3.4	7.1	20.8
15	54.7	5.3	4.6	35.4	—5.8	1.2	—	25.8	47.8	85.0	4.4	11.5	26.4
16	61.9	9.1	4.7	24.3	0.7	1.9	—	32.7	39.0	79.0	1.7	7.8	28.[illegible]
17	58.4	4.0	7.0	30.6	1.4	0.57	—	38.7	51.8	70.0	1.79	10.4	9.5
18	65.4	9.0	3.6	22.0	8.8	2.5	15.9	44.4	39.8	72.2	1.96	2.44	—
19	57.5	6.1	7.9	28.5	—5.1	0.9	—	36.9	51.3	72.0	2.2	11.3	11.8
20	54.7	8.6	5.1	31.6	—12.9	1.7	—	36.9	62.3	75.8	3.8	21.3	0.8
21	55.4	12.7	2.2	29.7	—16.8	5.8	3.9	46.9	49.2	65.9	1.6	8.9	—
22	60.3	9.3	3.1	27.3	—1.1	3.0	—	20.5	55.9	75.7	1.9	26.9	23.0
23	66.9	10.3	3.1	19.7	10.1	3.3	—	22.6	59.4	74.6	1.6	15.2	18.0
24	57.4	10.6	4.6	27.4	—11.0	2.3	—	46.9	27.4	82.5	0.8	2.9	26.7

Table 5

Chemical analyses of schists (by weight %)

Oxides	Schist and micaceous meta-sandstone of the Lower Formation (analysis nos.)				Remnants of schist and micaceous quartzite in granite (analysis nos.)				
	25	26	27	28	29	30	31	32	33
SiO_2	64.0	54.67	69.84	75.40	75.24	69.86	59.06	61.20	69.17
TiO_2	0.64	1.86	0.37	0.25	0.35	0.25	1.11	1.03	0.31
Al_2O_3	16.21	21.91	19.17	14.46	12.54	14.55	19.02	16.21	16.00
Fe_2O_3	4.4	2.17	1.29	1.57	2.71	1.55	2.10	2.85	1.49
FeO	6.30	4.87	0.43	2.58	2.20	2.58	5.45	7.50	3.58
MnO	0.09	0.05	Trace	0.02	0.04	0.01	0.06	0.07	0.03
MgO	1.51	3.69	0.36	0.32	1.60	2.98	3.45	3.70	2.08
CaO	0.60	0.91	0.07		0.85	0.28	0.82	0.80	0.56
Na_2O	0.13	1.09	0.68	0.14	2.38	0.79	1.12	0.06	1.34
K_2O	3.90	5.45	5.23	3.29	0.62	5.22	4.92	4,14	3.52
Cr_2O_3	—	—	—	0.003	—	—	—	0.01	—
V_2O_5	0.01	—	—	—	0.01	—	—	0.01	—
P_2O_5	—	—	—	—	0.10	0.11	0.08	0.36	0.11
CO_2	0.20	—	—	0.12	0.37	—	0.07	0.07	—
S_{total}	—	—	—	—	0.01	—	0.13	0.03	—
Losses in heating	2.50	3.4	2.14	2.28	2.10	2.10	2.30	2.04	1.79
H_2O	—	0.12	0.05	0.13	—	0.04	0.60	—	0.13
SO_3	—	—	0.18	—	—	0.17	—	—	0.16
F	—	—	0.09	—	—	—	—	—	0.09
Σ	100.57	100.19	99.90	100.59	101.12	100.49	100.29	100.07	100.36

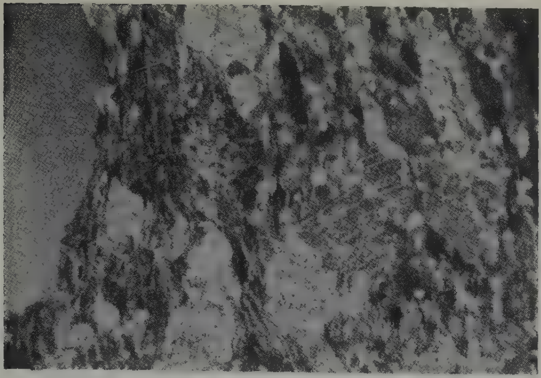


FIGURE 5. Newly formed oligoclase in quartz-mica schist.
Thin section, 32 X, Nicols crossed.

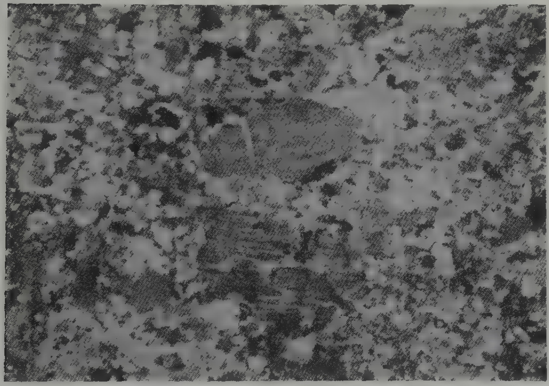


FIGURE 6. Microgranoblastic quartzite with microcline inclusions.
Thin section, 20 X, Nicols crossed.

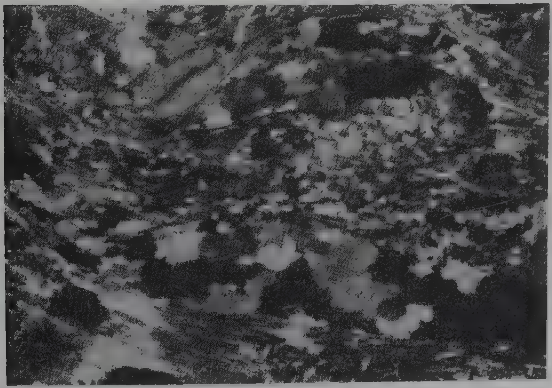


FIGURE 7. Staurolite-mica schist with lenticular quartz inclusions.
Thin section, 20 X, Nicols crossed.

intercalations, often differentiated into lenses (up to 1 cm), thus lending the schists an "augen" aspect (Figure 7). Biotite and muscovite occur together, in intercalations showing constrictions and swellings. The muscovite is developed on biotite, with the most intensive muscovitization occurring in feldspathic schist and at the contact with granitized rocks.

Garnet and staurolite form idioblastic grains usually associated with micaceous intercalations.

The schist structure is lepidogranoblastic to "augen". Schist from remnants in granitized rocks and from the Lower Formation have similar mineral composition, textural and structural features, and the similarity corroborated by chemical analysis (Table 5).

The Lower Formation rocks from the Ingulets mine differ from similar rocks in other areas by their coarser scales of mica minerals, in feldspathization, muscovitization of biotite; the presence of staurolite, andalusite, clinopyroxene; and by "augen" structures. The higher degree of metamorphism in the Ingulets mine is characteristic also of rocks of the iron-ore formation, as noted by many students [1].

This stronger metamorphism is obviously related to granitization. The gradual and imperceptible transition from granite to granitized rocks, together with the similarity in mineral composition and the presence of remnants of replaced rocks, may indicate that the granites are a final product of the replacement process of greenstone and Lower Formation rocks.

The replacement of metabasics and schists of the Lower Formation was accompanied by considerable ionic migration. For a graphic illustration of this migration, the chemical analyses of rocks have been converted by the

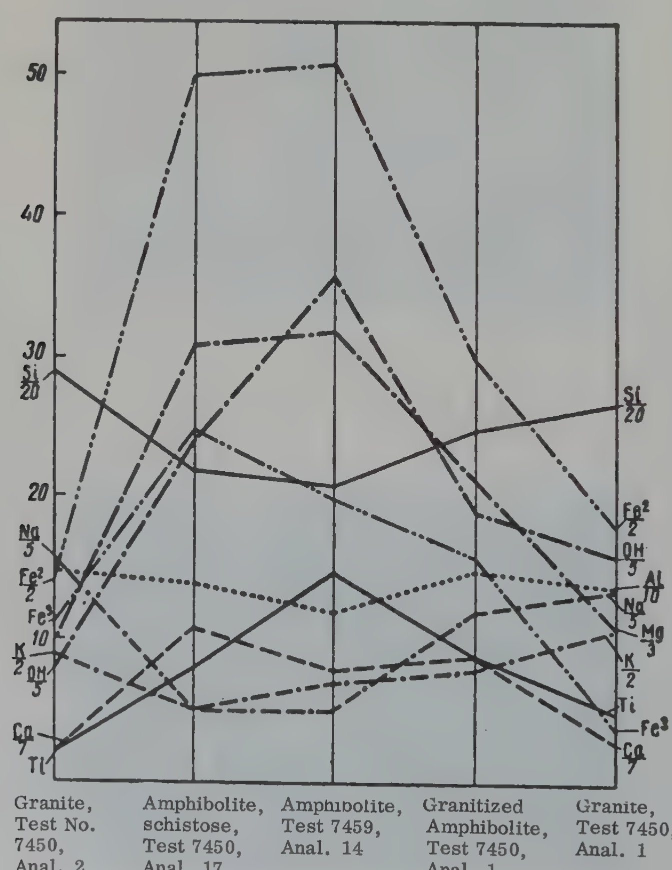
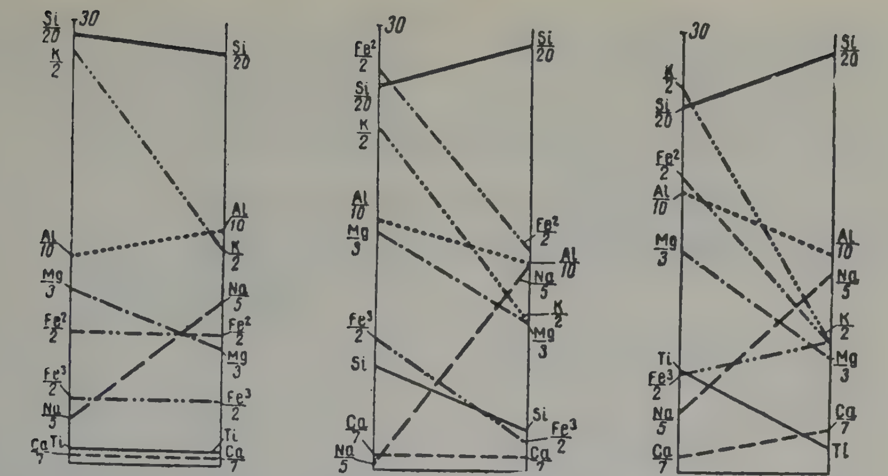


FIGURE 8. Change in the composition of amphibolite, in granitization (after T. Barth)



Quartz-mica schist, Test 7475, Anal. 30 — Granite, Test 7475, Anal. 6 — Mica schist with staurolite, Test 7450, Anal. 32 — Granite with staurolite, Test 7450, Anal. 8 — Staurolite-mica schist Test 7450, Anal. 21 — Granite, Test 7450, Anal. 7

FIGURE 9. Change in the composition of schist from the Lower Formation, in granitization.

. Barth method and are represented in a iagram (Figures 8, 9).

Inasmuch as the most strongly metamorphosed rivoy Rog rocks are associated spatially with ranitization segments, and because of the ommunity of folded structures in metamorphic ocks and the linear textures of plagiogranite, can be assumed that the folding and metaorphism of the Krivoy Rog series were conemporaneous and interrelated with the foration of the Ingulets granite.

REFERENCES

1. Belevtsev, Ya. N., Geologicheskoye stroyeniye i zheleznyye rudy Krivorozhskogo basseyna. [GEOLOGIC STRUCTURE AND IRON ORES OF THE KRIVOY ROG BASIN]: Gosgeolizdat, 1957.

2. Goroshnikov, B.I., Ob izverzhennykh gornykh porodakh v gal'kakh konglomeratov nizhney svity krivorozhskoy metamorficheskoy serii. [EXTRUSIVE ROCKS IN THE PEBBLES FROM CONGLOMERATES OF THE LOWER FORMATION, KRIVOY ROG METAMORPHIC SERIES]: Doklady Akad. Nauk SSSR, t. 109, no. 1, 1956.

3. Kulishov, M.P., Petrotektonicheskiye issledovaniya porod Krivogo Roga. [PETROTECTONIC STUDIES OF THE KRIVOY ROG ROCKS]: In the collection, Geologiya i genezis rud Krivorozhskogo zhelezorudnogo basseyna. Izd-vo Akad. Nauk USSR, 1955.

4. Nikol'skiy, A.P., O stratigrafii rayona Krivogo Roga. [STRATIGRAPHY OF THE KRIVOY ROG REGION]: Doklady Akad. Nauk SSSR, t. 82, no. 6, 1952.

5. Nikol'skiy, A.P., Novyye dannyye o dokembrii Krivogo Roga. [NEW DATA ON THE PRECAMBRIAN OF KRIVOY ROG]: Tr. Laborat. geol. dokembriya, vyp. 2, 1953.

6. Nikol'skiy, A.P., Neob"yektivnaya kritika. [NONOBJECTIVE CRITICISM]: Izv. Akad. Nauk SSSR, ser. geol., no. 6, 1954.

7. Polovinkina, Yu. Ir., Osadochnyye i magmaticheskiye kompleksy Ukrainskogo kristallicheskogo massive. [SEDIMENTARY AND METAMORPHIC COMPLEXES IN THE UKRAINIAN CRYSTALLINE SHIELD]: Materialy Vses. n.-i. geol. in-ta, 1954.

8. Polovinkina, Yu. Ir., Stratigrafiya, magmagmatizm i tektonika dokembriya Ukrainskoy SSR. [STRATIGRAPHY, IGNEOUS ACTIVITY, AND TECTONICS OF THE PRECAMBRIAN IN THE UKRAINIAN SSR]: Tr. Laborat. geol. dokembriya, vyp. 2, 1953.

9. Polovinkina, Yu. Ir., Yeshche raz o vozrastnykh vzaimootnosheniyakh

Krivorozhskoy metamorficheskoy svity i plagioklazovogo granita. [MORE ON THE AGE RELATIONSHIP BETWEEN THE KRIVOY ROG METAMORPHIC SERIES AND PLAGIOCLASE GRANITE]: Materialy Vses. n-i. geol. in-ta, vyp. 4, 1955.

10. Semenenko, N. P., O vzaimootnoshenii granitov i kristallicheskikh slantsev Krivogo Roga. [RELATIONS BETWEEN GRANITE AND CRYSTALLINE SCHIST IN KRIVOY ROG]: Uch. zap. Denpropetr. univers., 1938.

11. Semenko, N. P., Dokembriy Ukrainskoy SSR. [PRECAMBRIAN IN THE UKRAINIAN SSR]: Tr. Laborat. geol. dokembriya, vyp. 2, 1953.

12. Usenko, I. S., Arkheyskiye metabazity i ul'trabazity Ukrainskogo kristallicheskogo massiva. [ARCHEAN METABASICS AND ULTRABASICS IN THE UKRAINIAN CRYSTALLINE MASSIF]: Izd-vo Akad. Nauk USSR, 1953.

Institute of Geologic Sciences,
Academy of Sciences
Ukrainian S. S. S. R.,
Kiev

Received, 3 November 1959

SUBALKALI VARIETIES OF SIBERIAN TRAPROCK IN THE BOL'SHAYA BOTUOBIYA BASIN (RIGHT TRIBUTARY OF THE VILYUY)[1]

by

V. V. Yudina

INTRODUCTION

During recent years many publications on ıbalkalic varieties of pyroxene teshenite-type ·aprock have appeared. According to some :udents [1, 2, 18], deposits of iron and Iceland ɔar are associated with them. Opinions differ ɜ to the origin of these rocks; e. g., crystalli-ıtion out of a special alkalic branch of differ-ıtiation [10] versus the crystallization of a ·agma contaminated at depth, or in situ [1, 3]. With such a state of affairs, we believe .at the data presented here will be of some in-·rest, insofar as it traces the development of definite province of traprock magmatism and e place of some, however few, varieties of ıbalkalic rocks in this process.

This material was gathered by the author ıring a geologic survey and special studies in e basin of the Bol'skaga Botuobiya River (right ibutary of the Vilyuy), in 1955-1956 and 1960. ɔme of the chemical analyses have been taken :om data by V. P. Ledneva (V. S. E. G. E. I.) who ırried out a special field survey along the ɔl'shaya Botuobiya.

I. GEOLOGIC STRUCTURE

The area under study is located in the eastern ırt of the Siberian platform, at the junction of ɾo noncontemporaneous platform structures: ·e early Paleozoic Angara-Lena trough [4] and e late Paleozoic Tunguska synclise. Gently ipping Lower Ordovician deposits are developed ·re (Figure 1) represented by assorted lime-one, dolomite, marl, and calcareous sand-one, with a total thickness of about 200 m. ıey are overlain by thin continental Lower ·rmian formations: sandstone with conglomerate nses, shale, and sandstone, with a visible ickness up to 60 m. Both sections are cut by aprock intrusions, mostly sills, and are overlain in turn by Lower Jurassic sands, sandstone, and conglomerate.

Occurring in a comparatively narrow band along the middle Bol'shaya Botuobiya course is a north-northwesterly trending fault zone, the south terminal of the Akhtaranda zone of crushing [10]. It is associated with the eastern margin of the Tunguska synclise, and is characterized by multiple crushing stages, intrusive activity, of long duration and intensive hydrothermal mineralization. It is here that our subalkalic traprocks are developed; for this reason, the present exposition deals mostly with its igneous and metasomatic formations. At least two phases of faulting, accompanied by igneous and postmagmatic phenomena, are present in this area.

The earliest faults, trending mostly northwest and often showing a considerable displacement of sedimentary blocks, were feeders for the traprock magma. Formed at that time were sills and more complex bodies, often strongly differentiated, showing evidence of an active intrusion of magma (drag folds in the enclosing rocks, the presence of numerous xenoliths and remnant blocs). These intrusions, now consolidated, were crushed by subsequent faulting. The traprocks show zones of extremely strong shearing, cleavage planes, and slickensides. The displacement in faulting further complicates the correlation, what with the faults trending northwest and northeast. Associated with this phase of faulting was the intrusion of small cutting bodies of amphibolitic subalkalic dolerite, locally amygdaloidal and autobrecciated, and cutting the sill-like intrusions.

The next phase of endogenetic activity, possibly accompanying a new phase of crushing, was the penetration of considerable volumes of hydrothermal solutions along fracture zones in the traprocks, the enclosing rocks, and along the intrusive contacts, with a vigorous metasomatism, in traprocks, as well as in the sediments. The traprock was altered to metasomatic teshenite-dolerite; this was followed by granitization and then by the formation of magnetite, serpentine, and calcite rocks. The sedimentary rocks, too, were metasomatized.

---

[1]Subshchelochnye raznovidnosti Sibirskikh trappov basseyne r. Bol'shoy Botuobii (pravyy pritok r. lyuya), pp. 79-97.

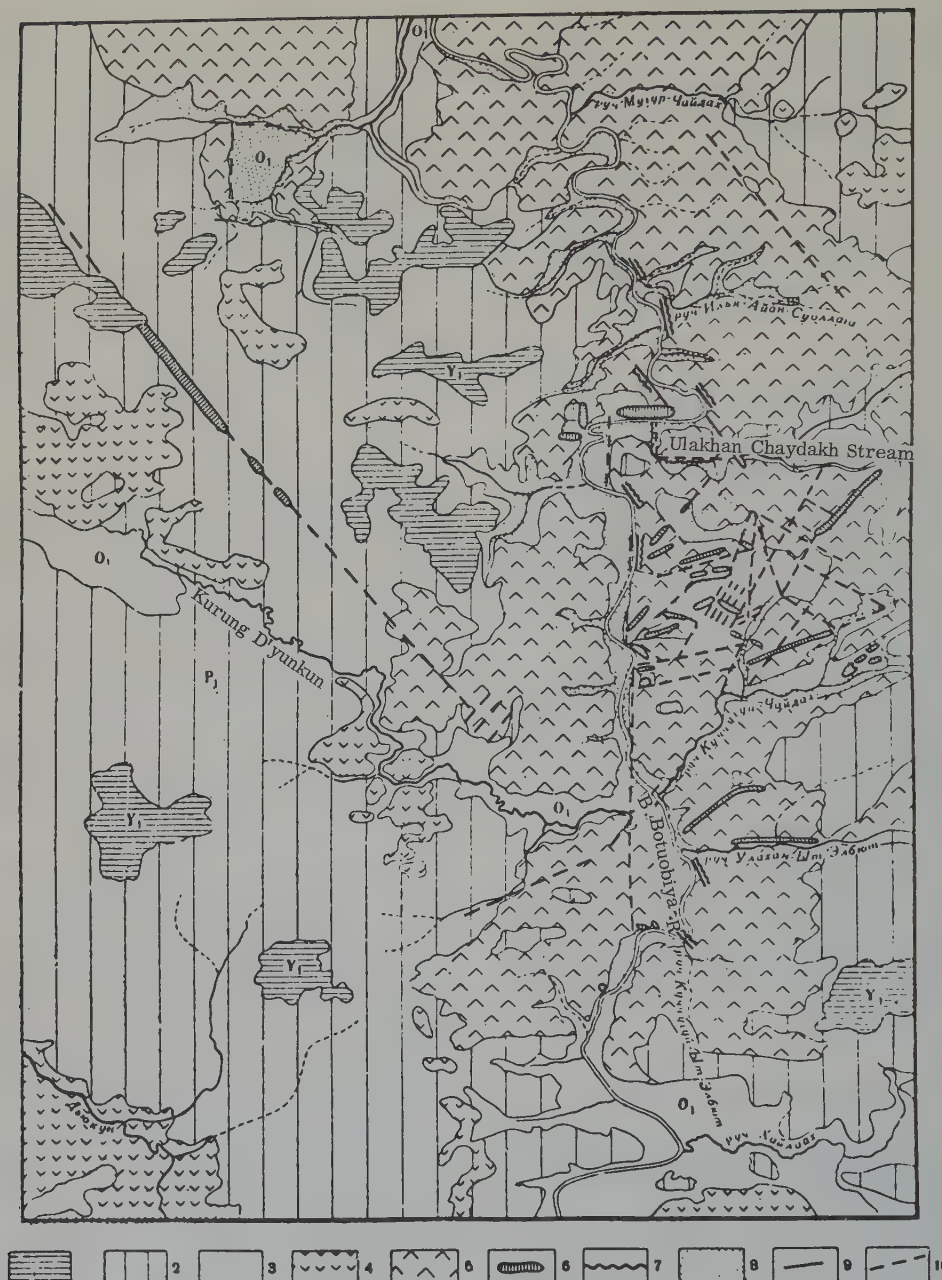


FIGURE 1. Geologic map of the middle course of Bol'shaya Botuobiya River (by N.V. Kind, M.P. Metelkina, and V.V. Yudina; supplemented by V.V. Yudina)

1 - Lower Jurassic sandstone, gravel, and conglomerate lenses; 2 - Lower Permian sandstone, silty shale, conglomerate lenses; 3 - Lower Ordovician dolomite, oölitic limestone, stromatoliths, sandstone; 4 - undifferentiated traprock sills of an early stage; dolerite, porphyritic microdolerite; differentiated intrusions of later stages; 5 - stratified sills: dolerite, pegmatitic dolerite; 6 - cutting bodies of subalkalic dolerite, often amygdaloidal; metasomatic rocks; 7 - metasomatic teshenite-dolerite and apodoleritic skarn; 8 - skarn rocks O_1 and P_1; 9 - known faults; 10 - assumed faults.

Thus, traprock development in this area roceeded as follows:

1. Undifferentiated intrusions of an early age, largely sills in the gently dipping upper nd lower Paleozoic deposits.

2. Differentiated younger intrusions associ-ed with the Botuobiya stage of crushing, and ieir culminating postmagmatic activity: 1) ratified intrusions; 2) small cutting bodies of ıtobrecciated amygdaloidal subalkalic dolerites ıd amphibolic subalkalic dolerites with rhombic roxene; 3) the formation of metasomatic rocks ıd hydrothermal veins.

II. UNDIFFERENTIATED EARLIER INTRUSIONS

These intrusions, largely sills, crystallized ıt of a "dry" magma, are quite common here, s everywhere else in the Vilyuy basin. Their ickness ranges from 20 to 120 m. They con-st of quite monotonous dark-gray medium- to ne-grained normal dolerite. Zones enriched magnesial olivine are commonly present at e base of the thickest bodies. The tempered eriphery of these sills is made up of dense yptocrystalline microdolerite. Sills in lower ıleozoic stratified shale-carbonate sections e marked by their large areal dimensions, gular form, and a small thickness of tempered ones (1.5 to 3.0 mm). Intrusions in Lower ermian areno-argillaceous rocks are irregular ıd inconsistent. Their tempered zones are 10 15 mm thick.

Dolerites of the undifferentiated intrusions e largely poikiloöphitic to ophitic, with in-rsertal and troctolithic segments, and a fairly ommon glomero-porphyritic texture. Basic agioclase (early precipitation of bytoxnite No. -89, and laths of labradorite No. 56-75 in the oundmass) accounts for 50 to 60% of the rocks; onoclinic pyroxene-pigeonite, 20 to 35% (10); $_{40}En_{45\ 50}$-Fs_{10-15} (γ = 1.719 to 1.720; α = 679 to 1.682; +2V = 48 to 52°; cγ = 35 to 41°). ivine Fa20-40 (-2V = 82-88°) accounts for 3 6%, and up to 14% in troctolite varieties.

The ore mineral, titanomagnetite, is present an amount up to 3%. Accessory apatite is esent in small amounts. Vitreous ground-ass is rare, being replaced usually by sec-ıdary minerals.

Porphyritic microdolerites are represented melanocratic porphyritic rocks with a taxitic oundmass (in places showing flow structure). ıey carry an abundance of fine xenoliths of the ıclosing sedimentary rocks and clastic grains quartz and feldspar. Incrustations, account-g for 20 to 30% of total rock are represented basic plagioclase (No. 78-80), olivine, and ss commonly by monoclinic pyroxene, plagioclase, ore mineral, and volcanic glass. In chemical composition, the normal dolerites correspond to the intermediate traprock type of the Tunguska synclise [7]. Alterations in sedi-mentary rocks contacting them are slight, con-sisting in compaction and burning, with the silt-stone and sandstone commonly turned to buchite.

III. DIFFERENTIATED INTRUSIONS OF A LATER STAGE, METASOMATIC AND HYDROTHERMAL FORMATIONS ASSOCIATED WITH THE BOTUOBIYA ZONE OF CRUSHING

1. Stratified Sill-Like Intrusions

As pointed out before, these intrusions penetrate mostly the northwesterly fault zones. Establishing the number and form of these bodies presents considerable difficulties; apart from their original somewhat sinuous form, the subsequent dislocations broke them up into seg-ments displaced relative to one another. For instance, the top of an intrusion exposed at the mouth of the Kuchchuguy-Yt-Elbyut creek oc-curs at about 50 m on the right bank, as against about 20 m on the left.

Three sills can be identified, more or less tentatively, in the middle course of the Bol'shaya Botuobiya: one, between the mouths of Kuch-chugay-Yt-Elbyut and Kuchchugay-Chaydaakh creeks; the second, between Orto-Chaydaakh and Ulakhan-Chaydaakh creeks; and the third, north of the mouth of the Ulakhan-Chaydaakh, as far as the Mugur-Chaydaakh.

The thicknesses of these intrusions are dif-ficult to estimate; however, they do not appear to exceed 70 or 80 m. Their structure is quite similar. They are dark-gray coarse-grained poikiloöphitic dolerites, with troctolitic dolerites carrying bytownite incrustations, at the base. The visible thickness of this unit is not over 8 m. Lenticular bodies of coarse-grained gabbro-dolerites with quartz and fine biotite scales in the groundmass are present in its middle part. Small sections (1 x 1m) of light-colored coarse-grained quartz gabbros with titaniferous pyro-xene and a higher titanomagnetite content have been also observed in the northernmost in-trusion.

Developed in the top of these intrusions are fine- to very fine-grained dolerites, locally amygdaloidal, up to 10 m thick. Their round amygdules, filled with actinolite, analcite, and zeolites, are usually small and unevenly dis-tributed. All three intrusions are marked by the presence of xenoliths of strongly altered stratified sedimentary rocks, either in nearly isometric chunks or in elongated stacks of layers. They very in size from small (1 x 2, 4 x 5 m) to large (30 x 40 m) and gigantic

(110 x 10 m). Their stratification is usually strongly disturbed by microshifts; in some instances the entire body of strata is strongly deformed, bent, and partly broken up.

All intrusions have been markedly crushed, with the formation of linear zones trending northwest, meridionally, less commonly northeast; within these zones, the dolerites are finely schistose and altered by the latest solutions to granitic, serpentine, and calcitic rocks. These zones are accompanied by trains of leucocratic metasomatic teshenite-dolerite with an extremely diversified structure and with pockets and accumulations of large crystals of aegirine-diopside, apatite, analcite, and radial zeolites.

All sill rocks belong to the normal series of crystallization differentiation of traprock magma. (Metasomatic teshenite-dolerites are not described in this chapter.)

Troctolitic dolerites are greenish-gray, dense, fine- to medium-grained rocks. Conspicuous in the smooth block surfaces are lustrous cleavage planes of large plagioclase bodies, up to 1 cm. These are glomeroporphyritic growths of zonal proto-anorthite (No. 93-71). The dolerite groundmass is poikiloöphitic; it consists of labradorite-bytownite No. 70, magnesial monoclinic pyroxene $Wo_{40}En_{45\;50}Fs_{10-15}$, and magnesial olivine Fa_{17-26} ($-2V = 82-89°$). The content of the latter reaches 25%. For the chemical analysis of this rock, see Table 1, sample 3167.

The coarse-grained poikiloöphitic dolerites are dark-gray massive rocks made by large oikocrystals of monoclinic pyroxene $Wo_{40}En_{40}F_{20}$ ($\gamma = 1.718$; $\alpha = 1.688$; $+2V = 50-52°$; $c\gamma = 42-44°$) with numerous ingrowths of plagioclase laths, large grains of olivine Fa_{40} ($-2V = 78-89°$), also grown through by plagioclase and irregular bodies of titanomagnetite.

These rocks almost always carry rhombic pyroxene-bronzite with 22-25% Fs ($-2V = 66-69°$). Their chemical composition is given in Table 1, sample 2.

Gabbro-dolerites with quartz and biotite in their groundmass are coarse- to large-grained gabbroöphitic rocks, mostly free of olivine. They consist of tabular basic plagioclase (No. 85-90, in tabular crystals of the first generation, and No. 52-70 of the second generation laths) and monoclinic pyroxene $Wo_{40}En_{25}Fs_{35}$ ($\gamma = 1.730-1.735$; $\alpha = 1.692-1.699$; $+2V = 48°$; $c\gamma = 46°$), always with ferrohypersthene Fs_{45} ($-2V = 58°$) in fairly coarse (up to 2 mm) prismatic crystals almost completely replaced by actinolite. The rare pseudomorphs on olivine consist of serpentine, talc, and magnetite. The interstices are filled with finely-scaled green biotite and xenomorphic albite, anorthoclase, and quartz. The groundmass accounts for about 5% of the rock. A chemical analysis of sample 4153^n is given in Table 1.

The quartz gabbros with titaniferous pyroxene are light-gray coarse-grained pegmatitic rocks consisting of plagioclase, monoclinic pyroxene, ore mineral, and quartz. Their plagioclase is andesine No. 45-48, in coarse (up to 8 mm) tabular crystals with their margins replaced by albite No. 8-10 and fine-scaled chlorite. The monoclinic pyroxene occurs in long prismatic idiomorphic crystals, 5 to 6 mm, brownish with a violet hue ($\gamma = 1.727$; $\alpha = 1.699$; $+2V = 58°$; $c\gamma = 50°$). Judging from its optic constants, this pyroxene carries up to 15% $CaTiAl_2O_6$ [17]. It is replaced in fractures by green and light-brown biotite; along margins by fibrous actinolite accompanied by finely dispersed ore mineral. The ore mineral is titanomagnetite in regular square crystals, 0.5 to 0.7 mm, with numerous inclusions of plagioclase and less common sphene. Quartz is present up to 10%, as irregular grains in the interstices. There are pegmatitic growths of quartz and albite. The rock also contains apatite and sphene. Its chemical analysis is given in Table 1, sample 4153^z.

Rocks of marginal facies are represented usually by fine- to very fine-grained dolerites, in places amphibolitic and chloritic, occasionally with an amygdaloidal texture.

Present in the outer contacts of sills are zones of metasomatic alterations of argillaceous-carbonate rocks, up to 10 m thick. Rocks in the xenoliths have been similarly altered. Present here are diopside-albite and albite-epidote rocks, assorted skarns, pyroxene-garnet, garnet-serpentine-magnetite, as well as serpentine and calcitic rocks.

2. Small Cutting Bodies of Autobrecciated Amygdaloidal Subalkalic Dolerites and Amphibolitic Subalkalic Dolerites with Rhombic Pyroxene

The greatest concentration of these bodies has been observed on the right bank of the Bol'shaya Botuobiya, between Kuchchuguy- and Ulakhan-Chaydaakh creeks (Figure 1). The several exposures in the bank reveal their structure and relations to the enclosing rocks.

Exposed in the right bank, 7 km below Khaylaakh Creek, is a cutting body 14 m thick, oval in plan. It cuts an inclined sill of coarse-grained dolerite, and is made up of dark green-gray breccia-like amygdaloidal dolerite (Figure 2). This rock is extremely heterogeneous in texture: it is locally unconsolidated, friable, and full of amygdules, up to 1.5 cm; in other places it is dense, free of amygdules, with aphanitic, fine- to very fine-grained segments. (These varieties contain small xenoliths of coarse-grained dolerite from the enclosing intrusion.) The entire rock body is broken up by a dense network of fractures filled with calcite and zeolites; the surfaces of open fractures show a crust of greenish-brown garnet crystals. Present in the upper part of the amygdaloidal rock outcrop is

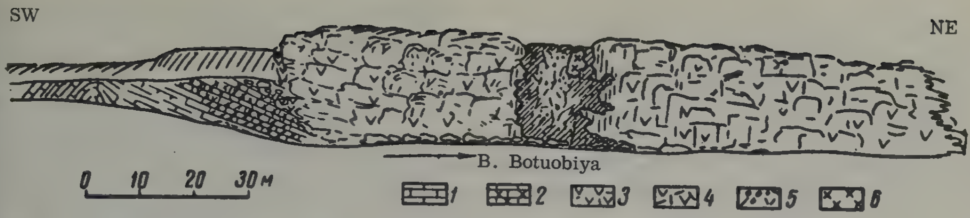


FIGURE 2. A cutting body of amygdaloidal dolerite.

1 - dolomite and marl O_1; 2 - skarn rocks O_1; 3 - porphyritic microdolerite of the tempered zone; 4 - coarse-grained poikiloöphitic dolerite; 5 - brecciated amygdaloidal dolerite; 6 - garnet skarn in amygdaloidal dolerite.

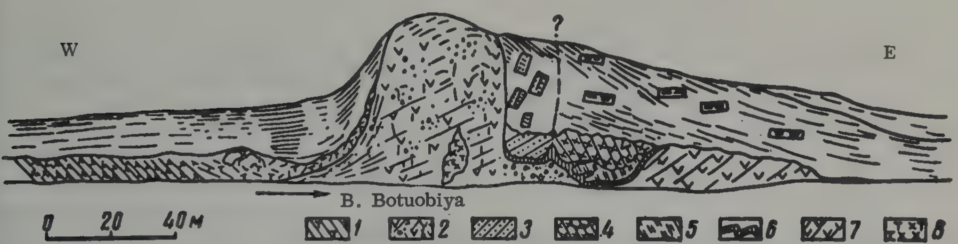


FIGURE 3. A cutting body of brecciated amygdaloidal dolerite.

1 - tuff; 2 - brecciated amygdaloidal dolerite; 3 - sandstone P_1; 4 - garnet skarn; 5 - banded hornfels; 6 - microdolerite from the tempered zone; 7 - medium-grained analcitic dolerite; 8 - altered tuff.

small segment, 0.7 x 0.8 m, of a green-gray ne-grained serpentine-garnet rock with relicts very fine-grained dolerite.

The mandelstein contacts with the enclosing oarse-grained dolerite are quite intricate, ith the mandelstein forming numerous apophy-es.

A similar but larger body is exposed 1.5 km ownstream, in the left bank (Figure 3), with e enclosing rocks much broken up. These are locks of Lower Triassic stratified tuffs,[2] and ower Ordovician carbonates, brought up to the ame elevation by faulting.

The cutting body forms a large columnar edge in sandstone and tuff (60 m high, rounded plan, 40 m diameter), sending off a number small apophyses into the crushed sandstone nd altered carbonate rocks. The rocks of this trusion are extremely heterogeneous. The olumnar ledge is made up of dark purple-green recciated aphanitic mandelstein changing down-ard to fully crystalline varieties, also full of mygdules, and then to medium-grained sub-kalic dolerites. Present in the mandelstein is fairly large xenolith of altered tuff, 7 x 16 m.

[2]The tuffs occur only in this area and are not entioned in the general description.

All these rocks are cut by numerous fractures, some showing growths of diopside and garnet crystals on their walls, with the middle parts full of zeolite, analcite, and calcite veinlets.

The cutting bodies made up of fully crystalline varieties are exposed in the right bank, 5 km below Kuchchuguy-Chaydaakh Creek. They are intruded into the crushed and displaced Ordovician dolomites and Permian sandstones and cut the sills. These bodies, unlike those described above, have rectilinear vertical to inclined contacts with the enclosing rocks. They consist of green-gray medium-grained amphibolitic subalkalic dolerites with rhombic pyroxene. Present at their top are zones of breccia-like mandelstein, up to 3 m thick.

These cutting bodies are made up of dolerite, with various degrees of crystallization but with common features. They contain postmagmatic analcite and a considerable number of autometasomatic minerals, including the aegirine-carrying pyroxene. This permits their assignment to the subalkalic group, although their sodium content is rather low.

The amygdaloidal autobrecciated porphyritic microdolerites are purple-black rocks with a diversified texture. Under the microscope, they are taxitic, showing alternating vitreous to better crystallized segments, the latter commonly reminiscent of fragments. This rock is

porphyritic, with the groundmass doleritic, hyalophilitic, to cryptostructural. Its incrustations are represented by plagioclase most of which has been replaced by isotropic analcite. The groundmass is plagioclase, monoclinic pyroxene, and titanomagnetite, and has been replaced to a considerable extent by finely fibrous to scaly aggregates of actinolite, chlorite, and zeolites. The numerous amygdules are filled up with radial natrolite and thomsonite. This rock also contains numerous clastic grains of quartz and potassium feldspar.

The amygdaloidal fine- to very fine-grained dolerites have a poikilitic to ophitic texture. They consist of plagioclase, monoclinic pyroxene (often with an aegirine component), occasional rhombic pyroxene, rare olivine, titanomagnetite, and analcite, and a considerable amount, up to 25% actinolite, chlorite, and biotite. Iddingsite, talc, and calcite are occasionally present. The amygdules are filled up mostly by acicular actinolite aggregates, occasionally with prismatic diopside crystals grown over by actinolite; also fairly large apatite prisms. Occasionally the amygdules are filled up with analcite.

Medium-grained amphibolitic subalkalic dolerites with rhombic pyroxene are dark to green-gray dense rocks, weathering to pea-size grains, because of the presence of coarse oikocrystals of monoclinic pyroxene saturated with fine laths of plagioclase. These rocks are taxitic, with the pyroxene-plagioclase poikilo-ophitic segments changing to leucocratic, made up of feldspars and analcite.

In addition to plagioclase (44.6 to 51%) and monoclinic pyroxene (15.5 to 30.9%), this rock contains rhombic pyroxene (0.8 to 4.9%), at times olivine, also titanomagnetite (3.1 to 4%), albite, anorthoclase, analcite, apatite, actinolite (18.3 to 19%), diopside, chlorophaeite, iddingsite, talc, chlorite, biotite, carbonates, zeolites, and vesuvianite.

The plagioclase occurs in places in glomeroporphyritic accumulations of coarse zonated protoblasts, up to 8 mm, with a bytownite core (No. 76-81) and labradorite margins (No. 55-62). The groundmass is represented by labradorite No. 62-68. Plagioclase of leucocratic segments is considerably more acid, being andesine No. 40-42. Crystals adjacent to interstices filled up with anorthoclase and analcite are zoned, with the margins of oligoclase No. 10-20. At the analcite boundary, the plagioclase is usually overgrown with albite. Plagioclase crystals are usually fresh-looking and only locally replaced in fractures by analcite, zeolites, and chlorite.

Monoclinic pyroxene forms colorless to slightly brownish coarse oikocrystals, showing in some thin sections an uneven fringe of greenish aegirine-carrying pyroxene, apparently autometasomatic.

Rhombic pyroxene shows up in all thin sections, as elongated prismatic crystals, often growing on olivine and monoclinic pyroxene; the reverse is true locally, with monoclinic pyroxene surrounding the rhombic. This pyroxene is colorless, with 2V varying from -69° to -53° (i.e., from hypersthene with 22% Fs to ferrohypersthene with 50% Fs). For the latter variety $\gamma = 1.718 \pm 0.002$; $\alpha = 1.710 \pm 0.002$. The rhombic pyroxene is replaced, often completely, by fibrous actinolite and chlorite.

Olivine is present in some thin sections, in small, rounded pseudomorphs of iddingsite, serpentine, and talc. These occur at times in the monoclinic pyroxene and occasionally carry plagioclase growths.

Anorthoclase occurs only in leucocratic segments of rocks carrying a more acid plagioclase where it forms large, up to 1 cm, xenomorphic grains in the interstices. It corrodes the albite fringes on plagioclase. Their refractive index is lower than that of Canada balsam: $\gamma - \alpha = 0.005$; $2V = -48°$. The anorthoclase is pierced through with fine apatite needles.

Analcite, too, occurs only in some of the thin sections, in a way similar to that of anorthoclase. It corrodes and replaces albite and is in turn replaced by diopside, chlorite, and radial natrolite. It is isotropic, as a rule, intensively fractured, and pierced by apatite needles.

Apatite occurs in comparatively large amounts, in very fine needles in the interstices, as well as in larger prisms, up to 4 mm long, piercing the pyroxenes and plagioclases.

Actinolite is the most common autometasomatic mineral. It is developed largely on rhombic pyroxene, less commonly on the monoclinic, in aggregates of long-fibered to acicular crystals, pale-green with a conspicuous pleochroism.

Its optical properties are inconsistent: $c\gamma = 0\text{-}20°$; $\gamma = 1.682$ to 1.690 ± 0.002; $\alpha = 1.670$ to 1.678 ± 0.002; the color intensity along γ is raised from yellow-green to blue-green, with an increase in the extinction angle and the refractive indices. Actinolite is replaced by fine-scaled chlorite and by rosettes of colorless talc. For the chemical analysis of these rocks, in samples 143 and 145, see Table 1.

Related to these cutting intrusions is a metasomatic alteration of the enclosing rocks, in exocontact zones several meters thick, leading to the appearance of assorted serpentine-calcite-garnet rocks.

3. Metasomatic and Hydrothermal Formations

Here we deal with the bulk of metasomatic rocks whose formation is related to post-magmatic endogenetic activity. We omit the description of altered lateral sedimentary rocks, the assorted pyroxene-garnet, serpentine-garnet,

pentine-magnetite, etc. We are most in-
ested in metasomatic rocks formed in the
ration of traprock.

As pointed out before, the stratified sills
ibit numerous linear zones of strongly
istose and altered dolerite. Such zones have
n traced in the Kuchchuyug-Yt-Elbyut Creek
a, along the meridional stretch of the river,
in several places at the sharp bends (Fig-
1). Their structure (across the strike) is
ilar everywhere. Trains of leucocratic
erites, diopsidic, aegirinic, albitic, analcitic,
zeolitic (metasomatic teshenite dolerite),
e heterogeneous in composition are present
heir peripheral parts; in the middle and most
istose part, they are gradually replaced by
pentine-garnetiferous, serpentine, and ser-
tine-calcitic rocks, in isolated pockets of
ious sizes, or along the fractures. The
kness of these metasomatic zones reaches
m, with the visible length up to 1 km.

n the stratified sills, metasomatic teshenite-
erite is formed on dolerites of all crystalli-
on stages; in dip cross-sections of the crush
zones, leucocratic heterogeneous teshenite-
erite appears to cut the horizontal layers of
tolitic dolerite, coarse-grained poikiloöphitic
erite, and dolerite with quartz and biotite.
rse-grained teshenite-dolerite formed on
shed aphanitic dolerite of the tempered zones
have been observed. The outlines of these
ns are extremely intricate, with innumerable
-like apophyses along the fractures; the
sitions to unaltered dolerite are rapid, al-
gh not abrupt. Externally, these teshenite-
erites are quite distinctive; these are light
-gray to greenish and blue-gray rocks, ex-
nely heterogeneous in texture. Their slabs, polished with water, exhibit particularly well the haphazard alternation of fine- and coarse-grained, leucocratic and melanocratic segments, segregations, and veinlets of very coarse crystals of pink zeolites and green-black aegirine-diopside, with numerous pockets of coarse crystals of apatite (up to 2 cm), sphene, and brown garnet (Figure 4).

Microscopic texture and particularly the composition of these rocks have been determined by two factors: first, by the composition and structure of the original dolerite, and second by the degree of alteration. Present in the rock are varieties of blastoophitic and blastopoikiloöphitic textures, with the coarse-grained segregates exhibiting an idioblastic texture.

Participating in the composition of these rocks are relict minerals of the original rock: olivine, assorted plagioclases (from bytownite to andesine-oligoclase), colorless monoclinic pyroxene, and titanomagnetite. In addition, newly-formed minerals, albite, analcite, zeolites, scapolite, diopside, aegirine-diopside, sphene, apatite, actinolite, blue-green hornblende, biotite, chlorite, occasionally magnetite, brown garnet, and calcite are present. The content of newly formed minerals is variable, and their distribution uneven; generally speaking, their content rises going toward the middle parts of metasomatic zones, with their numerous pockets of coarse aegirine-diopside idioblasts and radial aggregates of zeolites.

Now for a brief description of the metasomatic minerals. Albite, when present, forms fringes on plagioclase, replacing it along some fractures.

Analcite, too, is not always present. It occurs

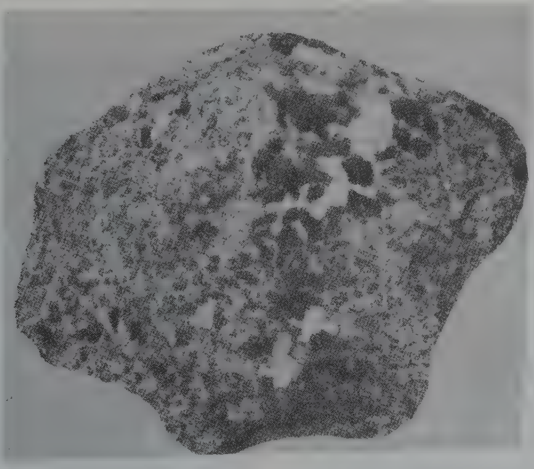


FIGURE 4. Metasomatic teshenite-dolerite.

A segment of coarse crystals of aegirine-diopside, analcite, natrolite, 3/4 natural size.

in xenomorphic grains, at times with a perfect cleavage, isotropic to slightly anisotropic, with quite low refractive indices. It usually replaces plagioclase and minerals of the groundmass, locally forming coarse xenoblasts of analcite. The latter contain relict laths of plagioclase (Figure 5) forming an extremely thin growth of green (chlorite) fibers over it. The analcite is often replaced by radial zeolites.

FIGURE 5. Metasomatic teshenite-dolerite.

A coarse xenoblast of analcite with plagioclase laths surrounded by chlorite. Thin section 252 X 53, without analyzer.

Anorthoclase is quite rare, occurring in serrated xenoblasts with a poorly expressed cleavage (γ is somewhat smaller than in Canada balsam; $2V = 47°$); its position in the rock is similar to that of analcite.

Diopside is quite common, being formed on the primary colorless monoclinic pyroxene, whose coarse oikocrystals are commonly altered, either wholly or along the margins, to an aggregate of fine isometric blastic grains of pale green diopside (Figure 6). In deeply metamorphosed rocks, diopside forms the cores of coarse idioblasts with the edges overgrown with vivid green aegirine-diopside. Its optic constants: $+2V = 48°$; $c\gamma = 40°$.

Aegirine-diopside is quite characteristic of these rocks, although its content is variable. It forms the peripheral zones in crystals of colorless pyroxene and in blastic diopside grains, and also occurs in individual idioblastic grains. Quite often these grains are broken up into a number of growths piercing the plagioclase, lending these segments a poikiloblastic structure (Figure 7). Its composition is inconsistent, and its color varies from light-green to deep grass-green. Pelochroism varies from golden-yellow along α to deep-green along γ; $c\gamma = 50$ to $68°$; $+2V = 64$ to $92°$; in grains with maximum values of $c\gamma$ and $2V$, $\gamma = 1.754 \pm 0.00$[illegible] $\alpha = 1.722 \pm 0.002$; $\gamma - \alpha = 0.032$. The aegirine component content ranges from 10 to 50%.

Sphene is present from 1 to 4%, with isolated pockets of copper-yellow envelope-shaped crystals up to 7 mm. In the rock, sphene forms fringes about titanomagnetite but is just as common in diablastic growths with aegirine-diopside and in poikilitic growths in plagioclase.

Apatite, too, is quite common. Unlike the fine needles of apatite in normal dolerites, it occurs here in large (at times up to 2 cm) excellently formed prisms piercing all minerals.

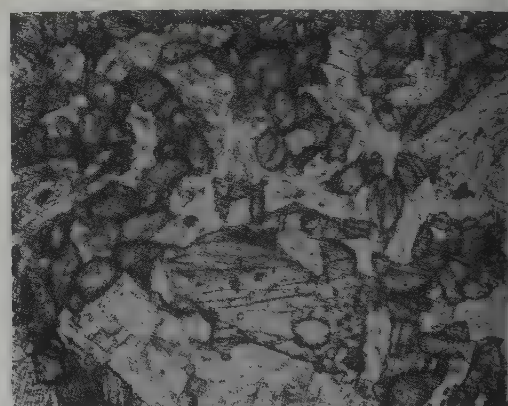


FIGURE 6. Metasomatic teshenite-dolerite.

Diopsidization of monoclinic pyroxene. Thin section 277, X 58, without analyzer.

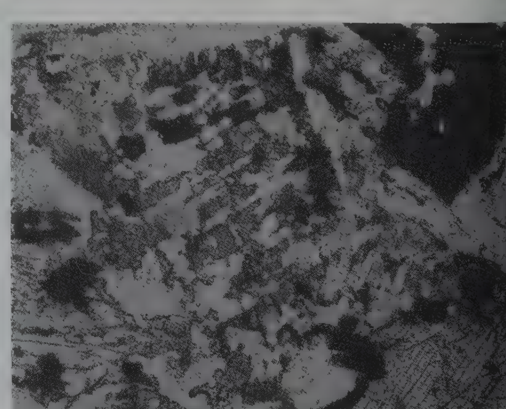


FIGURE 7. Metasomatic teshenite-dolerite.

Replacement of plagioclase by aegirine-diopside. Thin section 199, X 45, without analyzer.

The blue-green hornblende, when present in ı sections, forms fine rod-like crystals, up). 2 mm, growing in zeolites, or forms rod- ɛ growths about the aegirine-diopside grains; = 23-25°; $\gamma - \alpha$ = 0. 002 to 0. 003.

Zeolites constitute the principal rock-forming ıerals, in some segments, where they ac- ınt for up to 45% of the rock. Most typical the radial zeolites, natrolite and thomsonite; ɔ present are stilbite, heulandite, and lau- ntite. The zeolites are formed mostly on ;oclase, as well as on analcite and pyroxene.

Chlorite is a later formation. It occurs in ɛ-green rosettes with anomalous interference ɔrs, and is developed on zeolites. Also pre- t are earlier green-brown to green chlorites; 'ever, they appear to be relicts. The chemi- analyses of various metasomatic teshenite- ɛrites are given in Table 1 (samples 113, , 183, 97, 3198-III, and 4149a).

Garnet skarns. All of the above-named rocks subject to replacement by garnet skarns. ernally, these are light-colored to motley, rse-grained, very rough rocks with numerous ched-out caverns. The garnet forms coarse morphic crystals, up to 5 mm, mostly es, with colorless margins. They are sotropic, as a rule, with fairly common torial twins. The garnets often contain cts of monoclinic pyroxene with poikolitic wths of replaced plagioclase (Figure 8). rstices among the garnet crystals are filled nalcite, serpentine, and calcite. Their ıtive content is variable. The chemical com- ition of a serpentine-garnet skarn is given 'able 1 (sample 196).

Serpentine rocks. The garnet rocks gradu- change to serpentine, until light-colored yellow-green anchimonomineral serpentine rocks, often reminiscent of nephtite, are formed. These consist of serpophite or else of a fine fibrous chrysotile aggregate with fairly common pseudomorphs of bastite (possibly on proxene). Some of the serpophite segments exhibit a rash of extremely fine incipient garnet crystals of a later generation. Also present are magnetite serpentine rocks with an abundance of very small magnetite crystals (Analysis 4153u, Table 1).

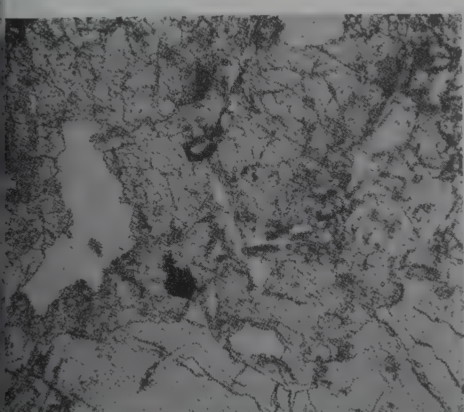


FIGURE 8. Garnet skarn with relicts of teshenite-dolerite.

ɦin section 196, X 22, without analyzer.

Hydrothermal veins. The intrusive bodies are threaded in many places by a network of thin (2 to 5 cm) hydrothermal veins associated with tectonic and cleavage fractures. These are mostly later low-temperature analcite and calcite-zeolite veins. Brushes of diopside and garnet crystals are common along their walls. Less common are quartz, quartz-albite, and diopside veins with magnetite, sphene, scapolite, and chlorite.

IV. CHEMICAL COMPOSITION OF IGNEOUS AND METASOMATIC ROCKS FROM THE BOTUOBIYA ZONE CRUSHING

Given below are the chemical analyses of dolerites from all phases of the intrusions, as well as analyses of metasomatic teshenite-dolerite and apodoleritic skarns. The first six analyses are of the principal differentiates from sills of the first phase.

Changes in the content of individual components, in the course of hardening of an intrusions, are reflected fairly well in the variation diagram constructed from formula

$$\frac{FeO+Fe_2O_3}{FeO+Fe_2O_3+MgO} \times 100.$$

The diagram (Figure 9) shows a certain rise in the TiO_2 and Na_2O content; an appreciable increase in total iron and a decrease in magnesium; and a certain drop in the CaO and Al_2O_3 content. These changes reflect a normal evolution of the basalt melt, leading to the crystallization of ferruginous femic minerals and the micropegmatitic groundmass.

The next two analyses show the composition of subalkalic amphibolitic dolerite with rhombic pyroxene. Analysis was done on samples from the upper and lower intervals of an inclined

Table 1

Chemical analyses of trap- and metasomatic rocks from the Botoubiya zone of crushing; also analyses of pyroxene teshenites from other areas (in %; numerals are sample Nos.)

Components	3167	1	2	69^{a}	4153^{H}	$4153^{З}$	143	145	113
SiO_2	45.69	45.60	47.15	46.52	49.10	47.43	46.76	48.72	50.72
TiO_2	0.66	1.05	1.18	1.41	1.73	2.59	1.32	1.50	1.76
Al_2O_3	15.20	15.15	18.87	17.90	18.72	13.90	16.00	15.93	14.77
Fe_2O_3	1.76	3.33	4.04	4.57	3.07	13.37	6.44	4.52	6.68
FeO	8.17	10.35	6.85	8.35	6.80	5.38	6.06	8.21	4.19
MnO	0.02	0.27	0.08	0.07	0.17	0.20	0.16	0.16	0.11
MgO	16.93	10.51	6.17	6.17	3.86	3.67	8.04	5.57	5.04
CaO	9.08	9.76	12.63	12.54	11.03	7.95	10.04	11.82	10.32
Na_2O	1.78	1.49	2.38	2.12	1.73	2.78	2.81	2.70	3.37
K_2O	0.11	0.53	0.07	0.07	0.96	0.77	0.46	0.77	0.38
H_2O^+	—	—	—	—	1.76	0.58	—	—	
H_2O^-	0.57	1.26	0.57	0.28	0.72	1.33	1.06	0.30	1.14
P_2O_5	—	—	—	—	—	—	0.11	0.12	0.27
CO_2	—	—	—	—	—	—	—	—	
Cl	—	—	—	—	—	—	—	—	0.14
Losses to heating	—	0.59	—	—	—	—	1.48	0.46	1.9
Total	100.00	100.00	100.00	100.0	99.65	99.65	100.73	100.78	100.8
$\frac{FeO+Fe_2O_3}{FeO+Fe_2O_3+MgO}\times 100$	36.9	56.5	63.8	67.8	71.9	83.6	60.9	69.5	—

3167. Troctolitic dolerite. Converted from the modal composition. After V. P. Ledneva.
1. Normal dolerite enriched in magnesial olivine. After V. P. Ledneva.
2. Normal dolerite (2 km above the mouth of Kuchchuguy-Zakhar Creek). After V. P. Ledneva.
69^{a}. Dolerite with quartz and biotite; left bank of Bol'shaya Botuobiya (above Kuchchuguy-Chaydaakh Creek). Converted from modal composition. After V. P. Ledneva.
4153^{n}. Gabbro-dolerite with hypersthene, quartz, and biotite; right bank of Bol'shaya Botoubiya, 2 km below Ulakhan-Chaydaakh. Laboratory of Moscow Univ.*.
4153^{z}. Quartz gabbro with titaniferous pyroxene. Right bank of B. Botouobiya, 2 km below Ulakhan-Chaydaakh. Laboratory of Moscow Univ.
143. Subalkalic amphibolitic dolerite with rhombic pyroxene. Right bank of B. Botuobiya, 7 km below Ulakhan-Chaydaakh. Laborat. of the Arctic and Antarctic Inst. (A. A. N. I. I.). **
145. Subalkalic amphibolitic dolerite with rhombic pyroxene; same location as 143. Laboratory A. A. N. I.
113. Coarse-grained metasomatic teshenite-dolerite. Right bank of B. Botuobiya, at the mouth of Kochhuguy-Yt-Elbyut. Laboratory A. A. N. I. I.
265. Fine-grained diopsidic dolerite. Right bank of B. Botuobiya, 1 km below Il'ya-Ayan-Suollaga Creek. Lab. A. A. N. I. I.

*V. G. Tiptsova, Analyst for the Moscow Univ. Laboratory.
**N. K. Voznesenskaya and M. I. Gohvat, Analysts for the A. A. N. I. I. Laboratory.

cutting body, about 30 m thick. The difference in their chemical composition, a somewhat higher content of SiO_2 and FeO + Fe_2O_3, and a lower content of MgO in the upper sample 145, as in the first instance, is the result of crystallization differentiation, during solidification. Judging from their Wager and Deer factor, sample 143 may be correlative with

Table 1 (continued)

265	183	97	257	3198-III	4149^{a}	4115	3	4	5	6	196	4153^{y}
48.02	45.90	47.58	46.60	45.36	46.64	48.53	53.60	44.34	46.71	45,52	39.62	25.33
1.24	2.00	1.12	1.08	2.55	1.57	1.41	0.73	1.24	2.14	2,07	1.24	0.63
17.22	12.11	15.47	16.77	18.20	15.56	18.26	15.02	15.07	15.02	16,08	13.79	2.21
5.37	5.66	3.67	2.80	4.49	3.64	4.01	1.68	0.28	5.04	4,18	6.77	27.76
4.67	7.31	5.10	3.51	4.09	3.77	5.57	3.75	9.41	6.96	6,37	2.15	1.62
0.09	0.13	0.13	0.08	0.06	0.14	0.16	0.10	0.20	0.15	0,27	0.07	1.73
5.36	4.47	6.76	6.13	2.98	5.76	5.19	5.40	7.37	4.75	4,85	3.26	27.77
12.86	11.96	11.88	13.90	11.12	12.05	13.36	11.80	12.03	11.65	8,34	31.98	2.68
2.87	4.60	2.79	3.77	5.93	4.76	1.97	3.54	2.35	1.50	4,63	0.33	0.32
0.19	0.42	0.36	0.47	0.42	0.62	0.85	1.58	3.80	2.10	2,00	—	0.12
	—	—	—	—	3.76	0.27	—	—	3.09	4,42	—	8.48
1.07	1.32	1.18	0.92	4.80	0.87	0.44	1.13	3.28	1.03	0,68	0.47	1.46
0.15	0.37	0.13		—			—	—	—	—	0.10	
0.19	0.42	0.08		—	0.45	—	—	—	—	—	0.10	
0.19	0.14	0.21		—		—	—	—	—	—	0.18	
1.34	2.56	3.58	4.42	—	0.25	—	—	—	—	—	0.82	10.00
100.69	100.8	100.04	100.45	99.05	99.84	100.42	100.43	99.85	100.24	100	100.88	100.11
—	—	—	—	—	—	—	—	—	—	—	—	—

183. Coarse-grained metasomatic teshenite-dolerite. Right bank of B. Botuobiya, 5 km above Ulakhan-aydaakh. Laboratory. A.A.N.I.I.
97. Medium-grained metasomatic teshenite-dolerite. Right bank of B. Botuobiya, above Kuchchuguy-Ut-ouyt. Lab. A.A.N.I.I.
257. Medium-grained metasomatic teshenite-dolerite. Right bank of B. Botuobiya, below Il'ya-Ayan-ollaga. Lab. A.A.N.I.I.
3198-III. Coarse-grained leucocratic segment in metasomatic teshenite-dolerite. Right bank of B. tuobiya, above Kuchchuguy-Yt-Elbyut. Converted to the modal composition.
4149^{a}. A pyroxene-zeolite segment in metasomatic teshenite-dolerite. Same location as 257. Laborat. oscow Univ.
4115. Diopside-magnetite-zeolite-chloritic vein. Right bank of B. Botuobiya, below Ulakhan-Zakhar eek. Laborat. Moscow. Univ.
3. Leucocratic teshenite gabbro. Alamdzhakh River. After V. L. Masaytis.
4. Teshenite. Podkamennaya Tunguska River. After A. P. Lebedev.
5. Pyroxene Teshenite. Nizhnyaya Tunguska. After V.S. Sobolev.
6. Teshenite. Average, after R. Daly.
196. Serpentine-garnet rock with relicts of teshenite-dolerite. Same location as 183. Laborat. A.A.N.I.I.
4154^{u}. Magnetite-serpentine rock. Right bank of B. Botuobiya, below Ulakhan-Chaydaakh. Laborat. oscow Univ.; P.V. Diomidova, Analyst.

rmal dolerite, while sample 145 is similar to e quartz- and biotite-carrying dolerite. However, both of these samples have a higher Na_2O ntent, which takes them out of the normal series differentiates and puts them among subalkalic rocks. Samples 31 and 132 of amygdaloidal porphyritic microdolerites, analyzed by the flame photometry method, have also

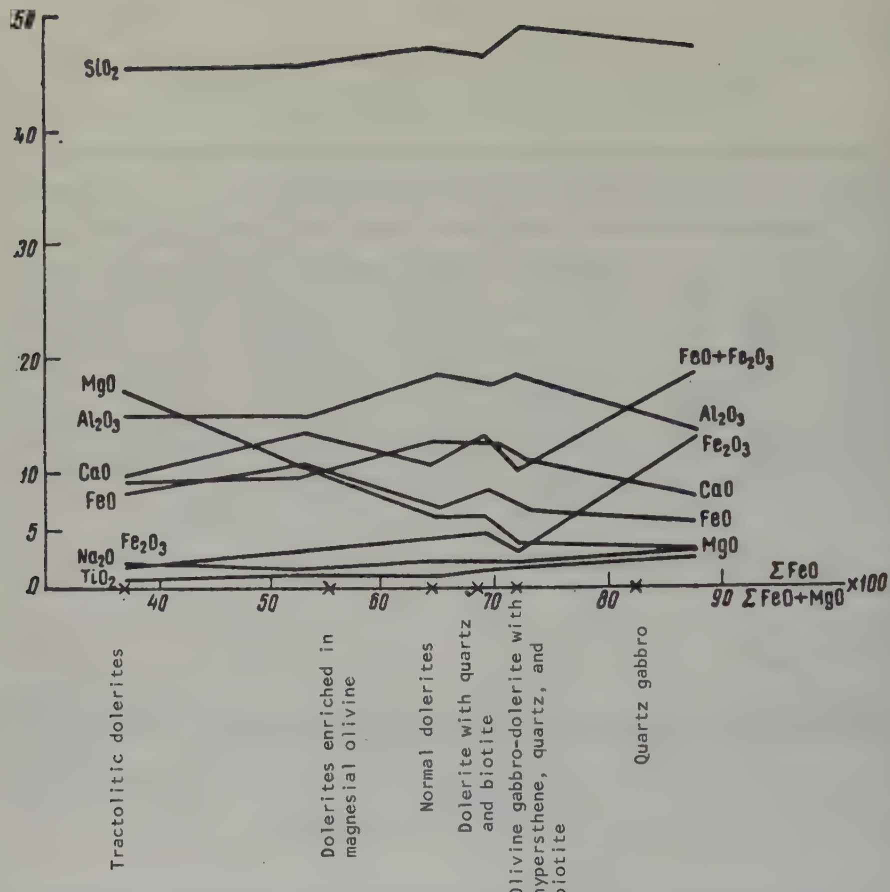


FIGURE 9. Variation daigram of chemical compositions of rocks of a normal series of crystallization differentiation.

been found high in alkalies (Table 2). Their composition appears to be most similar to that of the original melt.[3]

The next seven analyses (samples 113-4149[2], Table 1) are of metasomatic teshenite-dolerites. With a variable overall composition, they show a distinctly higher Na_2O, as high as 5.93%, with its highest values noted in samples from coarse-grained segments with their idioblasts of aegirine-diopside, xenoblasts of analcite, and radial aggregates of natrolite. Six samples, analyzed by the flame photometry method, show the same order of Na_2O content (Table 2).

Analyses 196 and 4153[u] (Table 1) are of apodoleritic serpentine-garnet skarns and magnetite-serpentine rocks. Table 3 gives a general idea of changes in the chemical composition of rocks in metasomatism, as converted to 100 cm^3. As compared with normal dolerites the teshenite-dolerites show a certain reduction in SiO_2, FeO, and MgO, and an increase of TiO_2, CaO, Na_2O.

Our rock groups so designated differ somewhat among themselves also in microelements. Later differentiates in the first phase sills show the appearance of Pb, Sn, Zn, and Mo, and a reduction in the Cr content. Subalkalic amphibolitic dolerite with rhombic pyroxenes, and amygdaloidal dolerites of the second intrusive phase, approach the normal dolerites, with Pb, Sn, Mo, and Ag present in metasomatic teshenite-dolerite. A few analyses of apodoleritic serpentine-garnet skarns show a higher Zn content.

Thus, the metasomatic teshenite-dolerites carry microelements characteristic of the residual portions of trap magma. This, too, shows their late appearance.

[3]It should be noted that the K_2O enrichment in samples 31 is due to the presence of K-feldspar xenocrysts.

Table 2

The alkali content in igneous and metasomatic rocks of the Botuobniya zone of crushing (in %; numerals are sample nos.)

Components	31	132	108	109	180	213	234	249	277	200	271
Na O	2.33	3.44	3.72	3.77	3.08	3.26	5.34	3.7	1.62	0.22	0.16
K_2O	1.20	0.65	0.35	0.20	1.42	0.50	0.36	0.31	0.25	0.20	0.05

Laboratory I.G.E.M.; L. Krutetskaya, Analyst.
31 — autobrecciated amygdaloidal ataxitic microdolerite.
132 — amygdaloidal fine-grained subalkalic dolerite.
108-277 — assorted metasomatic teshenite-dolerite.
200, 271 — calcite-serpentine-garnet rocks with relicts of metasomatic teshenite-dolerite.

CONCLUSIONS

The data presented above lead to certain con- sions on the development of traprocks within Botuobiya zone of crushing and on the role of alkalic derivatives in this process.

. Both phases of the late intrusive stage stallized out of a melt progressively en- ıed in volatiles and alkalies.

ı) The comparatively thin (70 to 80 m) in- sions of the first phase are appreciably ıtified, and differentiated up to the acid and ılic residue, dolerite pegmatites, while the ıcent areas contain intrusions of an early ;e: perfectly homogeneous sills, up to 120 ıick.

As demonstrated by V. L. Masaytis [10] for the Alamdzhakh traprocks, this process of crystallization differentiation is considerably facilitated by an enrichment of its original melt in volatile components which reduce its viscosity. In addition, a direct evidence of the presence of volatiles in the original melt is the development of amygdaloidal varieties in certain marginal segments of the sills, as well as a contact metasomatism of the enclosing rocks.

b) The cutting intrusions of the second phase crystallized out of a melt somewhat richer in volatiles and in N_2O. This melt was more active; for this reason, and under certain tectonic conditions, it formed intrusive bodies of the neck type, consisting of autobrecciated

Table 3

Change in the chemical composition of rocks, in metasomatism. Quantities in gm/100 cm^3 (Numerals — sample nos.)

mponents	1	97	257	265	319-8111	4149[a]	196	4153[y]
SiO_2	133.6	126.1	122.6	138.3	120.2	107.3	109.8	68.6
TiO_2	3.1	2.9	2.8	3.6	6.7	3.6	3.7	1.7
Al_2O_3	44.4	41.0	44.1	49.6	48.2	35,8	41.4	6.0
Fe_2O_3	9.7	9.7	7.4	15.5	11.9	8.4	20.3	75.2
FeO	30.3	13.5	9.2	13.4	10.8	8.6	6.4	4.39
MgO	30.8	17.9	16.1	15.4	8.4	13.2	9.8	75.2
CaO	28.6	31.5	36.5	37.03	29.5	27.7	95.9	7.2
Na_2O	4.1	7.4	9.9	8.3	15.7	10.9	0.99	0.9
K_2O	1.5	—	1.2	0.54	1.1	1.4	—	0.3
olume Veight	2.93	2.65	2.63	2.88	2.65	2.30	3.00	2.71

mandelstein. Dolerites of this intrusive phase underwent a sodium autometasomatism and an intensive autohydrothermal alteration.

2. It appears then that the Botuobiya zone of crushing housed a magmatic center with a peculiar trend in the evolution of its melt in the direction of an enrichment in volatile components and sodium. This center is the southern terminus of the Akhtaranda magmatic province [11].

3. Hydrothermal solutions are closely related to the development of the magmatic center and are a natural culmination of its activity. It should be noted here that the release of gases and solutions was initiated at earlier stages of this development. Amygdaloidal zones appear as early as in marginal zones of the first intrusive stage, which suggests a retrograde boiling-up and a liberation of the gas phase. The scope of these phenomena was apparently small.

Hydrothermal solutions emerged also in the solidifying of the second phase intrusions, as witness the presence in them of numerous amygdules, along with hydrothermal alteration and the formation of metasomatic bodies in exocontact zones.

The maximum hydrothermal activity appears to have been associated with the last stages of evolution of the magmatic center, when hydrothermal solutions penetrated the numerous zones of crushing and altered both the trap and sedimentary rocks. It is these residual solutions that were responsible for the vast areal skarns in sedimentary rocks and for the numerous trains of metasomatic teshenite-dolerites and apodoleritic skarns.

4. Thus the subalkalic rocks from these intrusions in the Akhtaranda magmatic province were formed at late and terminal stages of development of this magmatic center. They originated in processes other than a crystallization differentiation of magma. Two genetic groups of noncontemporaneous subalkalic rocks should be differentiated:

a) "Primary" igneous rocks, crystallized out of the melt batches considerably enriched in volatile components, and somewhat higher in Na_2O (up to 2.8%). They carry late-magmatic analcite and autometasomatic aegirine-pyroxene. Autometasomatic processes play a considerable role in the formation of these rocks.

b) "Secondary" metasomatic teshenite-dolerites, formed in the alteration of earlier solidified traprock, by postmagmatic solutions. The critical factor here is sodium metasomatism which raises the Na_2O content to 5.9%.

5) There is a difference in opinion on the causes of the magma enrichment in volatiles and alkalies. V.I. Gon'shakova [1] and L.P. Khryapina [18] associate this phenomenon with the alleged assimilation of lateral carbonate rocks, at depth. A.N. Solovkin [16] cites convincing evidence for the origin of analcitic basalt and teshenite out of the assimilation of marl by basalt magma, with an accompanying formation of intermediate desilicified hybrid rocks with 16 to 18% CaO and only 33 to 34% SiO_2. In the tectonic zone here described, the formation of subalkalic rocks cannot be associated with xenoliths in the intrusive bodies. Such xenoliths do not show any evidence of solution; also, they are far from being always associated spatially with subalkalic rocks. This phenomenon has been observed only where the xenoliths occur in a zone of crushing and metasomatic alteration. There is no sign of any desilicified hybrid rocks.

It appears that the formation of these rocks through an assimilation at depth also must be ruled out, because the melts show no deviation from standard, save for the enrichment in volatile components and N_2O; likewise, they produce a normal rock series, in crystallization differentiation.

The most plausible hypothesis appears to be that of V.L. Masaytis [10] who believes that the magma enrichment in volatiles and alkalies is the result of a long evolution of the magmatic center and is typical of intrusions taking place during the last phases of a traprock cycle. The association of alkalies and the volatile components is determined by a differential mobility of the alkalies, as suggested by many students.

REFERENCES

1. Gon'shakova, V.I., Petrokhimicheskiye kriterii svyazi endogennogo magnetitovogo orudeneniya na Sibirskoy platforme s differentsiatami trappovoy magmy. [PETROCHEMICAL CRITERIA FOR THE RELATIONSHIP OF ENDOGENETIC MAGNETITE MINERALIZATION IN THE SIBERIAN PLATFORM AND DIFFERENTIATES OF TRAPROCK MAGMA]: Izv. Akad. Nauk SSSR, ser. geol., no. 12, 1960.

2. Dmitriyev, Yu.I., Trappovyy magmatizm i gidrotermal'naya mineralizatsiya r. Chony. [TRAPROCK MAGMATISM AND HYDROTHERMAL MINERALIZATION OF THE CHONA RIVER]: Sov. geologiya, no. 10, 1959.

3. Zavaritskiy, A.N., Vvedeniye v petrokhimiyu izverzhennykh gornykh porod. [INTRODUCTION TO THE PETROCHEMISTRY OF EXTRUSIVE ROCKS]: Izd-vo Akad. Nauk SSSR, 1950.

Zaytsev, N. S., O tektonike yuzhnoy chasti Sibirskoy platformy. [TECTONICS OF THE SOUTHERN PART OF THE SIBERIAN PLATFORM]: In the book, "Voprosy geologii Azii". t. 1. Izd-vo Akad. Nauk SSSR, 1954.

Kennedi, Dzh., O roli vody v magme. [THE ROLE OF WATER IN MAGMA]: In the collection, "Zemnaya kora". Izd-vo in. lit., 1957.

Krasnov, I. I., and V. L. Masaytis, Tektonika Oleneksko-Vilyuyskogo vodorazdela v svyazi so stroyeniyem okrainnykh zon Tungusskoy sineklizy. [TECTONICS OF THE OLENEK-VILYUY WATERSHED IN CONNECTION WITH THE STRUCTURE OF MARGINAL ZONES OF THE TUNGUSKA SYNCLISE]: Materialy Vses. n.-i. geol. in-ta, nov. ser., vyp. 7, 1955.

Lebedev, A. P., Trappovaya formatsiya tsentral'noy chasti Tungusskogo basseyna. [TRAPROCKS IN THE CENTRAL PART OF THE TUNGUSKA BASIN]: Tr. In-ta geol. nauk Akad. Nauk SSSR, vyp. 161, 1955.

Lur'ye, M. L., O terminologii Sibirskikh trappov. [ON THE TERMINOLOGY OF SIBERIAN TRAPROCKS]: Materialy Vses. n.-i. geol. in-ta, nov. ser., vyp. 7, 1955.

Lur'ye, M. A., and S. V. Obruchev, Osonovnyye cherty effuzivnogo vulkanizma trappovoy formatsii Sibirskoy platformy. [MAIN FEATURES OF EXTRUSIVE TRAPROCK VOLCANISM IN THE SIBERIAN PLATFORM]: Materialy Vses. n.-i. geol. in-ta, nov. ser., vyp. 7, 1955.

Masaytis, V. L., Petrologiya Alamdzhakhskoy trappovoy intruzii. [PETROLOGY OF THE ALAMDZHAKH TRAPROCK INTRUSION]: Tr. Vses. n.-i. geol. in-ta, nov. ser., t. 32, 1958.

Masaytis, V. L., Tipy differentsiatsii trappovoy magmy v basseyne r. Vilyuy. [TYPES OF DIFFERENTIATION OF TRAPROCK MAGMA IN THE VILYUY BASIN]: Byul. Vses. n.-i. geol. in-ta, vyp. 1, 1958.

Nakovnik, N. I., Opredeleniye kolichestvennogo izmeneniya veshchestva pri gidrotermal'nom metasomatoze. [DETERMINATION OF THE QUALITATIVE CHANGES OF SUBSTANCES DURING HYDROTHERMAL METASOMATISM]: Zap. Vses. mineralog. o-va, ch. 87, vyp. 4, 1958.

13. Ostrovskiy, I. A., Voprosy elementarnoy teorii sistem s letuchimi i predpolozheniya o khode zatverdevaniya intruzii. [PROBLEMS IN ELEMENTARY THEORY OF SYSTEMS WITH VOLATILES AND HYPOTHESES ON SOLIDIFICATION OF INTRUSIONS]: Izv. Akad. Nauk SSSR, ser. geol., no. 5, 1952.

14. Ravich, M. G., O gidrotermal'nykh differentsiatakh trappov r. Vilyuy. [HYDROTHERMAL DIFFERENTIATES OF THE VILYUY RIVER TRAPROCKS]: Tr. N.-i. in-ta geologii Arktiki, t. 43, vyp. 3, 1954.

15. Sobolev, V. S., Petrologiya trappov Sibirskoy platformy. [PETROLOGY OF THE SIBERIAN PLATFORM TRAPROCKS]: Tr. Arkt. n.-i. in-ta, t. 43, 1936.

16. Solovkin, A. N., Assimilyatsiya mergelya bazal'tovoy magmoy. [ASSIMILATION OF MARLS BY BASALT MAGMA]: Doklady Akad. Nauk AzSSR, t. 3, no. 5, 1947.

17. Tsvetkov, A. I., Izomorfnyye zameshcheniya v gruppe besshchelochnykh piroksenov. [ISOMORPHIC REPLACEMENT IN THE ALKALI-FREE PYROXENES]: Tr. In-ta geol. nauk Akad. Nauk SSSR, vyp. 138, 1951.

18. Khryanina, L. P., O shchelochnykh differentsiatakh trappovoy magmy v basseyne r. Bakhty (Sibirskaya platforma). [ALKALIC DIFFERENTIATES OF TRAPROCK MAGMA IN THE BAKHTA RIVER BASIN (SIBERIAN PLATFORM)]: Tr. In-ta geol. rudn. mest., petr., mineralog. i geokhimii Akad. Nauk SSSR, vyp. 29, 1959.

Institute of Geology of Ore Deposits,
Petrography, Mineralogy, and Geochemistry,
Academy of Sciences, U. S. S. R.
Moscow

Received, 5 October 1960

BRIEF COMMUNICATIONS

VOLCANIC-TECTONIC STRUCTURES IN SOUTHERN KAMCHATKA[1]

by

V. V. Aver'yev and A. Ye. Svyatlovskiy

Tectonics and igneous activity are the two aspects of deep-seated movements in the earth's crust. Magma, because of its deep-seated origin, rises to the surface when the crustal movements involve a sufficiently thick segment and are sharply differential. Such phenomena are best expressed in the Pacific island arcs. The deep-seated movements (earthquakes as deep as 700 km) and volcanic activity are likened here to a "powerful pump" driving to the surface large volumes of magma, apparently an important factor in compensatory movements within narrow crustal belts.

The relative scope of these tectonic and igneous phenomena puts a definite stamp on their relationship under various structural conditions. Where a rigid framework "contains" the magma by lending to it its own shape, laccoliths, lappoliths, sills, veins, and other deep-seated intrusive bodies are formed, subordinate to the tectonics.

Where the igneous activity is in the ascendency, it becomes the controlling factor; in that event, discordant batholiths are formed. The magma surges up through the immense faults in the crust, opened by its pressure, and spreads over tens of thousands of square kilometers of the surface.

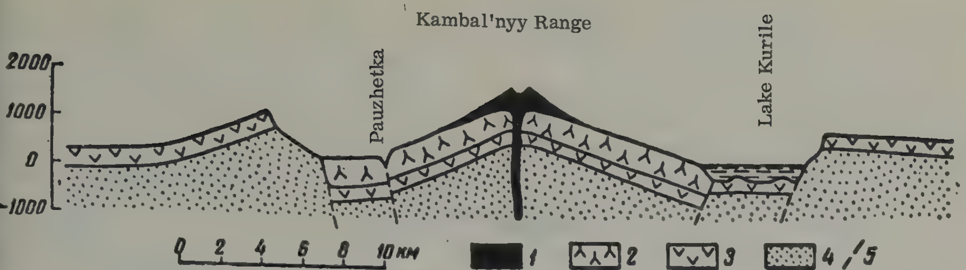
Volcanic-tectonic disturbances reflect the unity of tectonic and magmatic movements in volcanic provinces. Included here are volcanic-tectonic uplifts and subsidences and the resulting tension and annular faults, as well as grabens, calderas, etc.

Southern Kamchatka in the early Quaternary represented an arched uplift covered with andesite-basalt lava flows, spread over a leveled-off surface of folded Tertiary rocks. Toward the close of Early Quaternary time, t crest of this uplift collapsed to form a trough like depression, 20 to 30 km wide, trending submeridionally. The throw was up to 1000 m as determined by drilling through the present base of Quaternary lavas. In the beginning, t trough subsided progressively, to give a bert to the 400 m thick tuff section; however, the outpouring of Quaternary lavas was accompan by an uplift in the central part of the trough, which resulted in an anticlinal structure of th Kambal'nyy (Flounder) Range, in Late Quater nary time. It extends for 18 km along the trough and is 8 to 12 km wide, presenting a brachyanticline raised about 1000 m, as witness the occurrence of thin-bedded tuffs at an elevation over 1000 m in its axial part in contrast to less than 100 m at the foot.

Distributed along the crest part of the anti cline were the volcanoes whose eruptive cent are now recognized by the periclinal occurren of lavas and tuffobreccias. The highest uplift took place in the northern part of the anticline where its terminal is periclinal. The volcan centers migrated southward, as witness the p gressive thickening of the flows, and culmina in the Kambal'nyy volcanic cone (elevation 21 m) which is the southern end of the range. Fumarole activity persists in ancient craters north of that volcano, along the range.

At present the crestal part of the anticline and the lava flows, have been broken up. The western limb, made up of tuffs and overlain b lavas, forms a homocline dipping west at 20 to 25°. It is broken at its base by a meridion fault, now the valley of Pravaya Pauzhetka River. The flatter eastern limb, up to 15°, i downthrown for several hundred meters. In t northern part of the range, the axial part of t anticline itself has been offset by faulting, as witness the westerly dips of the tuffs. In the northwestern part of the uplift, the gentle dip are complicated by a system of northeasterly trending thrusts which have formed structura steps tens of meters high.

[1] Vulkano-tektonicheskie struktury Yuzhnoy Kamchatki, pp. 98-100.



Volcanotectonic structure of the Kambal'nyy Range, southern Kamchatka

l - Upper Quaternary extrusive complex: basic lavas and tuffs of the Kambal'nyy Range volcanoes; 2 - Quaternary dacites, andesites, and tuffs; 3 - Early Quaternary crystal-lithic tuffs of acid lavas, ignimbrites, basalts, andesites, and tuffobreccias; 4 - undifferentiated Tertiary basic lavas and tuffs, tuffaceous sandstones, and siltstones; 5 - faults.

ssociated with the rise of the volcanic-
onic Kambal'nyy Range was the formation of ghs at its foot. In the west and north, these ghs house the valleys of the Pauzhetka and rnaya Rivers, lined up by lava plateaus. se troughs probably are segments of an ly Quaternary trough, not involved in the ft but rather having undergone additional sidence during the formation of the Kambal' Range. A similar trough east of the Range a more complex structure. Following the dering of the east limb of the Kambal'nyy clinal uplift, a dacite extrusion occurred e (Dikiy Greben volcano) which formed a y massif trending northwest. As the dacite ma boiled up, it ejected large volumes of ice which then settled down about the exion. The pumice covered the upper terrace ne Ozernaya River and the Upper Quaternary bogs. The extrusion is broken up by a es of concentric normal faults; some of e face Kurile lake and were instrumental ne sinking of its western shores.

Lake Kurile (elevation 100 m above sea level sink 306 m deep. Its east and south shores formed by the eastern escarpment of the ly Quaternary trough; its north and west es, by young volcanic structures (Il'inskiy Dikiy Greben volcanoes). The lake itself x 10 m) is in a way a relict of the Early ternary trough, although its development also been affected by subsidence associated the activity of adjacent volcanoes. This anic-tectonic sink is similar in its origin to ain Central American lakes (Ilopongo, etc.).

he local earthquakes demonstrate that the of this early Quaternary trough, having ergone extensive reconstruction during the ternary, is still active. The earthquake of ember 5, 1952, with its epicenter off the shore of Kamchatka, submerged a strip ne north shore of Lake Kurile, about 100 m e.

The study of this area has been furthered by deep drilling in the structural trough, at the northwestern foot of the Kambal'nyy Range, in search for geothermal energy. Sandstones, presumably Tertiary in age (Pg + N), were penetrated at 650 m, in the Pauzhetka hot springs area. They are overlain by 100 m of andesite-basalts and tuffs, and almost 200 m of early Tertiary nitric-crystal-lithic dacitic tuffs, correlative to those present in upper intervals in the sides of the Early Quaternary trough. The upper interval, down to 380 m, is made up of Middle Quaternary tuffs and tuffobreccias, dacitic to andesitic, deposited partly in lacustrine basins. The section is capped by sand and gravel.

North of this area, major active volcanoes of southern Kamchatka are located in the bottom of the Early Quaternary trough which extends as far as the foot of the South Bystrinka Range.

The entire volcanic zone of the south Kamchatka Early Quaternary trough is similar in its activity (shield volcanoes → calderas → volcanic cones → calderas → acid extrusions) to the main volcanic zone of the Kurile islands. The latter can be regarded as a volcanic-tectonic range rising up from a structural trough bound in the west by the fault scarp of a post-Alpine Okhotsk sea platform. In the east, it is bound by the Lesser Kurile island chain which continues in the north as the Vityaz submarine range and Pacific oceanic "shield".

Laboratory of Volcanology,
Academy of Sciences, U. S. S. R.,
Moscow

Received, February 2, 1960

METHODS

THERMOGRAPHY OF CAUSTOBIOLITHS AND CLAY MINERALS[1]

by

N. V Logvinenko and S I. Shumenko

Various organic substances (humic compounds, carbonaceous matter, bitumens, tars, etc.) are frequently encountered in the study of argillaceous rocks. A 1 to 2% content of organic matter in clays and clay rocks is quite common. In argillaceous rocks of petroliferous formations, the organic content is often 5 to 10%.

It goes without saying that such organic impurities will affect the thermal curves of clay minerals, in the study of finely dispersed fractions. Despite that, this subject is inadequately treated in manuals and specialized works on thermal analysis.

The majority of authors recognize the noxious effect of organic matter (deformation of thermal curves) and recommend a preliminary processing of the rocks with various reagents, to eliminate the organic matter. For instance, a manual for petrographic study of clays, edited by N. F. Vikulova, recommends 3 to 6% H_2O_2, or sodium hypobromide [8]. It should be noted, however, that such methods are inconvenient, for the following reasons: 1) the processing holds up the study of clay rocks; 2) a total elimination of organic matter is impossible, as a rule; 3) the reagents act upon the clay minerals, affecting first of all the composition of absorbed cations.

N. I. Gorbunov and Ye. A. Shurygina [3] have also found out that a processing with hydrogen peroxide increases the amount of sesquioxides and complicates the thermogram. For these reasons, clays and clay minerals will have to be analyzed in the presence of organic matter, without any chemical processing.

The prevailing opinion is that the presence organic matter in clays causes a fairly flat exothermic peak in differential thermal curves in the 300 to 450°C temperature range. This effect was studied by L. P. Gmid [5] who corre lated thermograms for Maikop clays without a preliminary processing, and with processing with alcohol-benzene and caustic alkali. She has determined that humic compounds cause an exothermic maximum at about 600°C; bitumen at about 380°C; and "insoluble" organic matte at 385°C (after a processing with caustic alka and alcohol-benzene). In addition to overlooki the above consideration, L. P. Gmid also unfortunately overlooked the presence of 2 to 3% pyrite in the Maikop clays.

In order to determine which effects in thermal curves are caused by organic impurities, we must have thermographs of pure orga substances and of synthetic mixtures of known organic compounds and clay minerals.

Thermographs for various organic substances may be found in the extensive (althoug far from exhaustive) literature on thermograp of caustobioliths. It should be noted that most interest in the thermography of solid caustobioliths has been shown by students of coking coal. Accordingly, the results are not famili to geologists. However, caution should be exercised in using these data. It is particular important to know the experimental conditions (the rate of heating, the atmosphere in the heat ing chamber, etc.), because they may affect th magnitude of thermal maxima and even distort and completely eliminate them (as is true for the oxidation effect of organic substances in a protective or neutral atmosphere).

Thermographic characteristics of humic acids can be found in the study by I. D. Sedletskiy and G. V. Shmakova [10]. Those authors carried out a differential thermal analysis of humic acid from peat (Figure 1-a) and chernoz and obtained almost identical curves. The fir endothermic effect, with a maximum at 90 to 110°C, is caused by hydration water; the second, at 630 to 635°C, is associated with a release of water in the transformation of carbox

[1]K termografii kaustobiolitov i glinistykh mineralov, pp. 101-109.

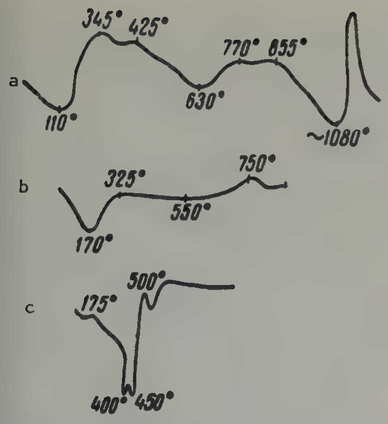


FIGURE 1. Thermal curves

a - humic acid; b - peat; c - boghead.

ıol, and methoxyl groups. An exothermic e at 200 to 400°C marks the combustion of ɔacids, while the 1100°C exothermic effect ects the breaking up and oxidation of benzene ns of humic acid. N. I. Gorbunova, I. G. urupa, and Ye. A. Shurygina [4] also present ermogram for humic acid. It is quite ilar to the Sedletskiy and Shmakova curves, ept for the absence of a well-defined exomic effect in the temperature range above C.

ccording to J. Stott and O. Baker [13, 17], ulose is characterized by a compound asymric exothermic effect which begins at 328°C, dly reaches a maximum at 380°C, then dies n gradually, up to 489°C. To dampen this ct, the authors "diluted" the cellulose with Al_2O_3.

I. Kanavets, B. K. Klimov, and K. I. ɔisova [6] obtained thermal curves for peat; of them is presented in Figure 1-b. It aps that the authors used a protective atmoere; as a result, the exothermic reactions xidation were not recorded. The peat mal curve exhibits the first endothermic ct with a maximum at 170 to 175°C (loss of ation water) and considerably weaker exomic effects in the 750 to 832° range.

peat thermogram which we have recorded er moderately oxidizing conditions, is vn in Figure 4-a. Interestingly enough, it uite similar to the humic acid thermogram ure 1-a), differing from it only in the somelower maximum temperatures, in the highperature range (which, incidentally, may be to the slow rate of heating, about 4°C per ute). Conspicuous in this peat thermograph the 140, 410, and 635°C endothermic efs, and the 300, 700, and 960°C exothermic cts.

We had no published data on the thermography of brown coals from the humus series; therefore we had to do some experimenting of our own. We have obtained almost identical differential thermal curves for the Ukrainian and Moscow types of coals. One such thermogram is presented in Figure 4-f. It shows that the brown coals are characterized by endothermic effects with maxima at 140°C (loss of hydration water) as well as at 400 and 510°C (430 and 540°C for the Moscow basin brown coals). As will be shown below, these effects are typical for all coals (except for anthracties). The two coal types are marked also by endothermic effects in the 700 to 740°C and 880 to 890°C ranges. Inasmuch as the recording was done under moderately oxidizing conditions, the curves show a marked exothermic rise with a maximum at about 310 to 320°C.

A thermal curve obtained for boghead (Figure 1-c) by N. A. Nechitaylo, M. N. Sokolova, and S. G. Sarkis'yan [9] is an example of the thermographic characteristics of sapropelitic coals. This curve shows an endothermic effect in the temperature range up to 175°C and a sharp twin endothermic effect with the maxima at 400 and 450°C, typical of many coals. The authors experimented with a high heating rate of about 18 to 20°C per minute; this probably is the reason for the merger of two endothermic effects into a single one. The absence of the thermal effect of oxidation suggests the presence of a protective atmosphere. Unfortunately, the authors give no interpretation of their thermograms.

Hard coals have been more extensively studied, thermographically, than peat and brown coals [1, 2, 6, 12-17]. A series of thermal curves for various hard coals, after H. Glass [12], recorded in a protective atmosphere, is given in Figure 2, 2-e. Typical of all these curves are endothermic effects in the 90 to 115°C range, associated with the release of hydration water; also two endothermic effects in the 400 to 600°C range. The first is associated with the fusing of coals; the second, with an intensified liberation of volatile components and a repeated hardening. According to H. Glass [12] the intensity ratio of these two effects is different for coals with a different content of volatiles; as such it may serve as a classification criterion and a measure of their carbonization. It should be noted that the Glass classification has not yet been generally accepted.

H. King and W. Whitehead [13, 14] concluded after their thermal study of hard coals in a vacuum that exothermic maxima shift with a higher carbon content: from 425°C (charcoal) to 530°C (semianthracite). In another work; H. King and D. Kelly [15] have demonstrated that a drop in the volatile content raises the temperature of exothermic effects, from 450°C to 520°C (in a vacuum).

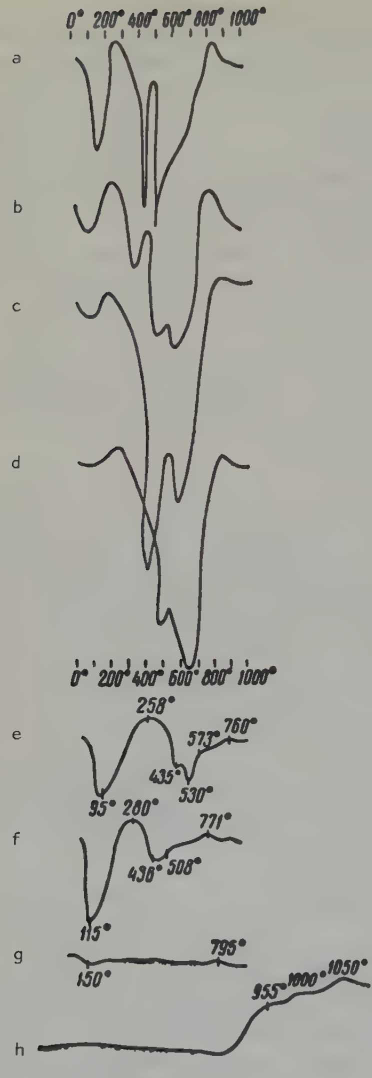


FIGURE 2. Thermal curves

a - long-flame coal, 48% volatiles; b - gas -- long-flame coal, 38.6% coal; c - rich coal, 27% volatiles; d - smoke coal, 19.1% volatiles; 3 - mark G_1 coal, ash content 7.86%; f - mark D coal, ash content 5.39%; g - anthracite; h - graphite.

Van-Chzhao-syun and G. N. Markarov [1], unlike the majority of authors, carried on the thermographic studies of hard coals in an oxidizing atmosphere. Figure 2, e-f, presents two such thermograms.

The authors state that decomposition and surface oxidation of coals take place in the 150 to 300° C range (exothermic bulge), as confirmed by analytic data. They are in accord with H. Glass in their interpretation of the twin zigzag peak in the 400 to 530° C range, as indicating a baking stage of the coal. The differential the- mal curve rises again in the 510 to 540° C ran- By that time, most of the volatiles have escap- while the curve slope indicates the compactio- of semicoke and its transformation to coke, a- companied by an intensive elimination of oxyg- bearing compounds. A slight absorption of h- in the liberation of residual hydrogen, and a more orderly orientation of the carbon surfa- takes place above 750° C. The authors conclu- that, in coal thermography, the maintenance of an inert medium is not necessary. A comparison of their curves with those obtained wi- a protective atmosphere (such as in Figure 2, a-d) is a convincing demonstration.

K. Kröger and A. Pohl [16], in their differ- ential thermal study of Ruhr coals, analyzed three coal components: vitrinite, exinite, and micrinite (nontransparent coal matter). Their thermal curves turned out to be different from one another. The vitrinite curve is the riche- in thermal effects, followed by the exinite curve. The micrinite curve is almost devoid of thermal effect, duplicating the zero line, which suggests a thermal inertia for this coal component.

As anticipated, the most metamorphosed coals, the anthracites, approach graphite in thermographic characteristics. Figure 2-g i- an anthracite thermogram, after B. K. Kanave- B. K. Klimov, and K. I. Chibisov [6]; Figure 2-h is a graphite curve, after N. I. Gorbunov, I. G. Tsyurupa, and Ye. A. Shurygin [4].

Theremograms for various bitumens have been published recently by N. A. Nechitaylo et al [9]. Some of them are presented in Figure 3, a-f. Unfortunately, the authors give no interpretation of the several thermal effects; however, the very aspect of these curves indicates the variety of bitumens, even within individual groups (crude oils, ozokerites, asphaltites).

B. K. Klimov et al [7] analyzed a number o- oil shale samples. Two of their thermogram- are given in Figure 3, g-h. Outwardly, they are quite similar to the hard coal thermogram- being characterized by the distinct endotherm- effect of the hydration water loss, at 120 to 150° C, and two endothermic effects in the 400 to 600° C range, the latter merging at times, as in coals, into a twin peak (Figure 3-h). Th- absence of exothermic effects indicates that th- authors used a protective atmosphere.

In concluding this brief review of the therm- graphy of caustobioliths and their components, we must note the two essential factors lowerin- the value of data so obtained: 1) a total lack of uniformity in the experimental method (with the methods themselves often not properly described); 2) with a few exceptions [2], mineral impurities in caustobioliths, such as

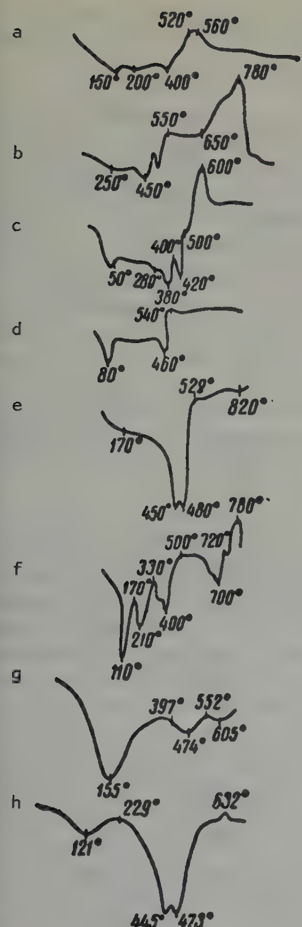


FIGURE 3. Thermal curves

Minusinsk paraffin base crude; b - Severo-
k asphalt base crude; c - Minusinsk ozero-
; d - Shor-Su ozerokite; e - asphaltite; f -
altite; g - Azerbaydzhanian oil shale; h -
onian sapropelitic (blue-green algae) oil
e.

te, marcasite, clay minerals, etc., are red.

/e have recorded a series of thermograms rder to determine the nature and relative nsity of thermal effects for synthetic mix-s of clay minerals and caustobioliths. We for that purpose standard samples of yanovo kaolinite and Oglanly bentonite, nented by peat, brown coal (Ukrainian and cow), and Mark D hard coal from the Don- i. e., by humus material of different de-s of metamorphism. Recorded in addition e curves for the Prosyanovo kaolinite mixed crude oil (from the Kharkov region wells), eken ozokerite, and Shor-Su asphalt. The ratios of clays and caustabioliths were selected to duplicate closely those occurring in nature.

Neither a protective atmosphere nor vacuum were used in our experiments, contrary to the prevailing practice. Exothermic effects caused by the oxidation of caustobioliths (combustion of organic matter in the 250 to 400°C range) are not strong enough to distort the thermograms and do not justify the considerable experimental complications arising in connection with the use of a protective atmosphere or a vacuum. We were also cognizant of the fact that neither condition is commonly obtained in thermal analyses of clay rocks and minerals.

The thermograms were recorded with the commercial photopyrometer FPK-55, which yields quite reliable results. Platinum was used for the thermal element; i. e., a platinum-rhodium thermocouple, 0.5 mm diameter. The thermocouple was protected by quartz covers, with the sensitivity of the device maintained by lowering the ballast resistance in the differential galvanometer circuit to 800 ohm. The weight of the sample was 2 gm, and the rate of heating 5 to 6°C per minute. Inasmuch as a supplementary furnace was used above 900°C, the thermal effect peaks in that range are somewhat flattened and stretched out along the horizontal axis. A slight lowering of the peak temperatures is possible, here. Prior to the analysis, the samples were crushed in a porcelain mortar and kept in a thermostat for 2 hrs, at 105°C.

Differential recordings of this study are presented in Figures 4-7. They show that the thermal characteristics of peat are quite similar to those of humic acids (Figure 1-a), differing only in the high-temperature maximum at 960°C; that, however, may be related to the slower heating.

Figure 4, a-d, presents thermograms for mechanical mixtures of Prosyanovo kaolinite and crushed peat; they show that the presence of as little as 2% peat is reflected in an endothermic effect at 235°C (loss of water hydration), and in an exothermic effect of oxidation, at 300°C. The other thermal effects of peat are missing in the thermograms of mixtures, even at a 10% peat content in kaolinite. It is of interest that the thermogram of kaolinite with a 5% peat content is quite similar to that of the Chasov"yarsk monothermite. This shows the extent to which the thermograms of clay minerals can be distorted by a small addition of organic matter, a fact to be remembered in the thermographic study of clays.

A series of thermal curves for kaolinite with brown and hard coals (ash content, 5.1 and 2.6%) also shows that up to 10% caustobiolith content in kaolinite is reflected in a low-temperature endothermic effect, at 150 to 200°C,

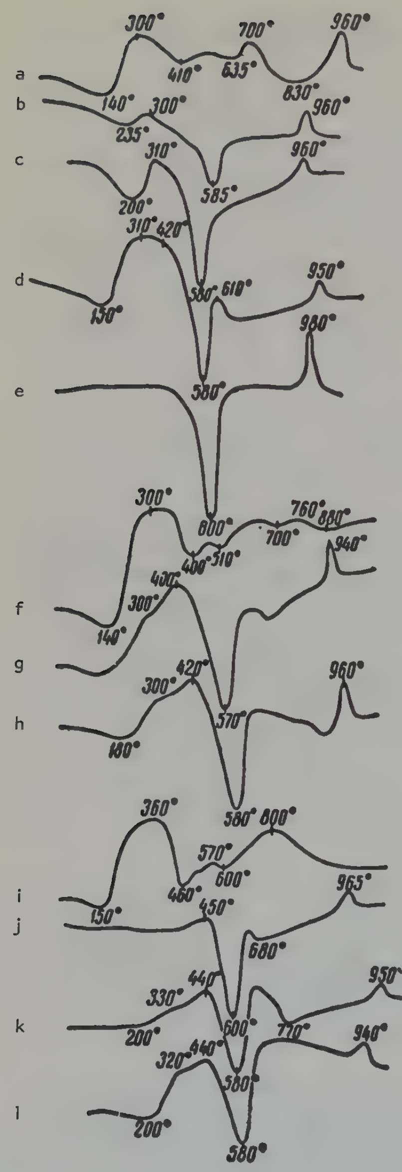


FIGURE 4. Thermal curves

a - peat; ash content, 3.8%; b - kaolinite with 2% peat; c - kaolinite with 5% peat; d - kaolinite with 10% peat; e - Prosyanovo kaolinite; f - Ukrainian brown coal, ash content 5.1%; g - kaolinite with 5% brown coal; h - kaolinite with 10% brown coal; i - hard coal, mark D, ash content 2.6%; j- kaolinite with 2% hard coal; k - kaolinite with 5% hard coal; l - kaolinite with 10% hard coal.

and an exothermic effect of combustion. The maxima of these exothermic effects are shifted over to a higher temperature range, as the organic matter becomes more metamorphosed. For example, the mixtures of kaolinite and peat show exothermic effects in the 300 to 320°C range; maxima for the kaolinite-brown coal mixtures are shifted to 420°C; and as far as 450°C for kaolinite-hard coal mixtures.

An increase in the organic content, besides shifting the exothermic maxima reflecting the oxidation, is accompanied by a widening of these effects. For instance, a strong endothermic effect in the kaolinite curve, at 570 to 580°C, splits in two the exothermic effect, to create a false impression of a second exothermic effect in the 600 to 700°C range (Figure 4, d, g, h, i, k). At an organic content of 10%, in the event it is represented by brown or hard coal, the entire thermogram acquires a convex shape (Figure 4, h, l). This extension of the exothermic effect of oxidation is determined apparently by oxygen deficiency for a rapid oxidation in a closed chamber, while the heating rate is sufficiently high.

Figure 5 presents differential thermal curves for mixtures of Oglanly bentonite with Mark D hard coal (ash content, 2.6%). The presence of as little as 2% organic matter is registered here by an exothermic effect at about 450°C. A low temperature endothermic effect of the loss of hydration water is marked by a similar endothermic effect of bentonite.

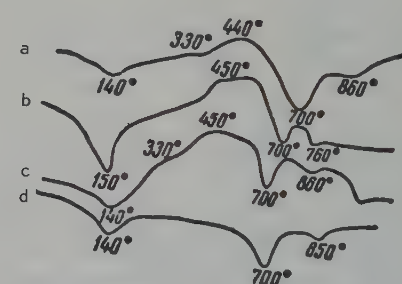


FIGURE 5. Thermal curves

a - bentonite with 2% hard coal mark D; b - bentonite with 5% hard coal; c - bentonite with 10% hard coal; d - Oglanly bentonite.

The possible presence of pyrite (marcasite) should be kept in mind in the study of clays with organic matter. In heating under oxidizing conditions, pyrite shows an exothermic oxidation effect in the 400 to 420°C range; as noted by A. I. Tsvetkov [11], the endothermic effect of dissociation, at 600 to 700°C, may be completely missing because of the oxidation of pyrite. The shape of exothermic oxidation peaks depends on the degree of dispersion and particularly on the percent content of pyrite in the clay. Figure 6 presents a series of differential thermal curves for mixtures of crushed pyrite and Prosyanovo kaolinite. With as little as 0.5% pyrite, the exothermic effect of its oxidation, with a

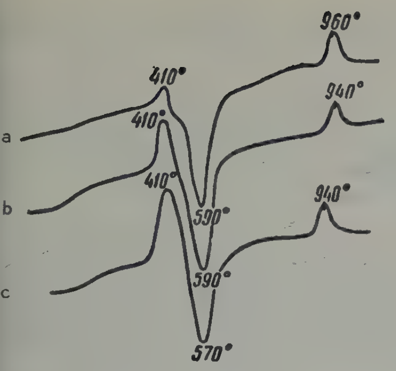


FIGURE 6. Thermal curves

- kaolinite with 0.5% pyrite; b - kaolinite ith 2% pyrite; c - kaolintte with 5% pyrite.

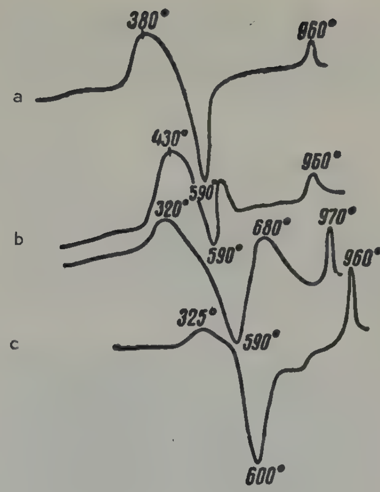


FIGURE 7. Thermal curves

a - kaolinite with 2% crude oil; b - same with 10% crude oil; c - kaolinite with 5% ozokerite; d - kaolinite with 5% asphalt.

aximum at 410°C, is quite noticeable. It idens with the increase of pyrite, and grows ore conspicuous; at 2% pyrite, it may be istaken for the effect of the oxidation of rganic matter.

To determine the effect of bitumens on the ermograms of clay rocks, we carried out xperiments with mixtures of Prosyanovo olinite and crude oil (Kharkov Oblast), heleken ozokerite, and Shor-Su asphalt. s shown in Figure 7, the curves so obtained e quite similar to those described above for ixtures of kaolinite and humus caustobioliths. ese thermograms also register the well-ex-essed exothermic oxidation effect at 320 to 30°C. This effect is most distinct for oil, id weakest for asphalt. The low-temperature dothermic effect is missing in these thermo-ams. The exothermic oxidation maxima for e crude oil, at 380°C, appear at 2% of it; ey appear in the 320 to 325°C range at a 5% ntent of either ozokerite or asphalt, despite e fact that these two curves were recorded at heating rate of 10°C per second.

SUMMARY

1. The presence of organic impurities de-rms the differential thermal curves of clay inerals; this should be taken into account by e students.

2. In mixtures of clay minerals and organic atter of the humus series, the exothermic ef-ct of the oxidation (combustion) of organic atter depends on the degree of metamorphism organic matter (taking into account the ecific conditions of the experiment) for the llowing temperatures: a) peat, maximum at 0 to 320°C; b) brown coal, 400 to 420°C; and hard coal, 440 to 450°C.

Considering the dependence of the maximum temperatures on various factors related to the experimental method, these figures should be interpreted as relative rather than absolute.

3. With a 10% organic content in clay, and over, the exothermic effect of oxidation may extend up to 700°C and higher, thus completely deforming the clay mineral thermal curve.

4. Mixtures of kaolinite with organic matter of peat, brown coal, and to a smaller extent of hard coal, show an endothermic effect at 100 to 235°C, caused by the loss of water of hydration and not characteristic of the kaolinite. This effect is difficult to identify in the curves for bentonite mixtures, because of the superimposed similar effect of bentonite.

5. Mixtures of clay minerals and organic components of petroleum series show an exothermic effect of oxidation, with maxima in the 320 to 430°C interval. With a higher organic content, the exothermic effect maximum migrates to a higher temperature range, as is the case for humic compounds. Because of the higher heat value of petroleum, the exothermic effect of its oxidation is 3 to 5 times stronger than for the same relative content of ozokerite and asphalt.

6. A 0.5 to 2% addition of pyrite produces a strong exothermic effect at 410°C, which widens with a higher pyrite content, to look like the oxidation effect for organic matter. For this reason, all clays carrying organic matter should be checked for iron sulfides.

8. At the present status of thermal analysis, a reliable identification of 1 to 5% organic content in clay, by type, by the differential thermal method alone is impossible.

REFERENCES

1. Van Chzhao-syun, and G. N. Makarov, Issledovaniye termogramm molodykh kamennykh ugley. [A STUDY OF THERMOGRAMS OF YOUNG COALS]: Koks i khimiya, no. 11, 1958.

2. Gebler, I. V. and Kh. A. Iskhakov, Osobennosti razlozheniya kizelovskikh ugley, obnaruzhivayemyye differentsial'nym termicheskim analizom. [DECOMPOSITION FEATURES IN KIZELOV COALS, AS DETERMINED BY DIFFERENTIAL THERMAL ANALYSIS]: Koks i khimiya, no. 5, 1958.

3. Gorbunov, N. I., and Ye. A. Shurygina, Termograficheskoye opredeleniye mineralov v ilistoy fraktsii pochv bez szhiganiya organicheskikh veshchetstv. [THERMOGRAPHIC IDENTIFICATION OF MINERALS IN THE OOZE FRACTION OF SOILS, WITHOUT BURNING UP THEIR ORGANIC COMPONENTS]: Doklady, Akad. Nauk SSSR, t. 67, no. 6, 1949.

4. Gorbunov, N. I., I. G. Tsyurupa, and Ye. A. Shurygina, Rentgenogrammy, termogrammy i krivyye obezvozhivaniya mineralov, vstrechayushchikhsya v pochvakh i glinakh. [X-RAY PHOTOGRAPHS, THERMOGRAMS, AND DEHYDRATION CURVES FOR MINERALS IN SOILS AND CLAYS]: Izd-vo Akad. Nauk SSSR, 1952.

5. Gmid, L. P., K litologii glinistykh porod chokraka i karagana Severo-Vostochnogo Kavkaza. [LITHOLOGY OF CHOKRAK AND KARAGAN CLAY ROCKS IN NORTHEASTERN CAUCASUS]: Tr. Vses. n.-i. geol.-razv. in-ta, nov. ser., vyp. 83, geol. sb., no. 1, 1955.

6. Kanavets, P. I., B. K. Klimov, and K. I. Chibisova, Termograficheskiy metod issledovaniya tverdykh topliv i protsessa ikh termicheskogo razlozheniya. [THERMOGRAPHIC METHOD OF STUDYING SOLID FUELS AND THE PROCESS OF THEIR THERMAL DECOMPOSITION]: Tr. I Soveshch. po termografii. Izd-vo Akad. Nauk SSSR, 1955.

7. Klimov, B. K., Ye. I. Kazakov, and N. L. Lutskovskaya, Primeneniye termograficheskogo metoda k issledovaniyu goryuchikh slantsev. [THERMOGRAPHIC METHOD IN THE STUDY OF OIL SHALES]: Tr. I Soveshch. po termografii. Izd-vo Akad. Nauk SSSR, 1955.

8. Metodicheskoye rukovodstvo po petrografo-mineralogicheskomu izlucheniyu glin. [MANUAL OF PETROGRAPHIC AND MINERAL STUDY OF CLAYS]: Gosgeoltekhizdat, 1957.

9. Nechitaylo, N. A., M. N. Sokolova, and S. G. Sarkisyan, O termograficheskom izuchenii bituminoznykh obrazovaniy. [THERMOGRAPHIC STUDY OF BITUMINOUS FORMATIONS]: Novosti neftyanoy tekhniki. Geologiya, no. 8, 1958.

10. Sedletskiy, I. D., and G. V. Shmakova, Termicheskaya kharakteristika guminovykh kislot. [THERMAL CHARACTERISTICS OF HUMIC ACIDS]: Doklady, Akad. Nauk SSSR, t. 35, no. 8, 1942.

11. Tsvetkov, A. I., Ob osobennostyakh termicheskogo analiza glin. [SPECIFIC FEATURES OF THERMAL ANALYSIS OF CLAYS]: In the book, "Issledovaniye i ispol'zovaniye glin". Izd-vo L'vovsk. un-ta, 1958.

12. Glass, H. D., Differential thermal analysis of coking coals. Fuel, no. 3, 1955.

13. Kirsch, H., Die Anwendung der Differentialthermoanalyse bei der Kohlenuntersuchung. Brennstoff-Chemie, B. 38, H. 5/6, 1957.

14. King, H. L., and W. L. Whitehead, Vacuum differential thermal analysis of coal. Fuel, No. 32, 1953.

15. King, H. L., and D. G. Kelly, Investigation of coking properties of coal by vacuum differential thermal analysis. Econ. Geol. vol. 50, 1955.

16. Kröger, K. and A. Pohl, Die physikalischen und chemischen Eigenschaften der Steinkohlengefügebestandteile. Brennstoff-Chemie, B. 38, H. 11/12. 1957.

17. Stott, J. B., and O. J. Baker, Differential thermal analysis of coal. Fuel, no. 32, 1953.

Kharkov State
University

Received, 12 February 1960

LOSSES TO SCIENCE[1]

OLEG DMITRIYEVICH LEVITSKIY (OBITUARY)[1]

by

. D. Afanas'yev, G. P. Borisov, K. A. Vlasov, D. S. Korzhinskiy, M. F. Mirchink, D. V. Nalivkin, Ye. V. Pavlovskiy, A. V. Peyve, V. I. Smirnov, N. M. Strakhov, F. V. Chukhrov, D. I. Shcherbakov, V. S. Yablokov

January 24, 1961, the life of O. D. Levitskiy ded; he was a discriminating student of ore posits, a master of broad generalization in e geology of rare metals, and an experienced end and adviser of field and mining geo- gists. He was the leader of a group of Soviet ologists dedicated to the creation of a raw- aterials base for the tungsten, tin, and other re-mineral industries of our country.

O. D. Levitskiy was born March 19, 1909, in tersburg, to the family of a mining engineer, graduated from the Geology Department of ningrad Mining Institute, 1930. Two years fore that, he began his field work by studying, der the direction of A. K. Boldyrev, the erlovgorsk ore deposit in eastern Trans- ykalia. This first contact with the geology of re elements determined the career of O. D. vitskiy as a life-long student of their com- ex nature. This dominant trend of his eative life is an example of dedication to a ngle scientific idea.

After graduating, O. D. Levitskiy worked as exploration party chief in Transbaykalian ngsten ore deposits. Between 1931 and 1935 was entrusted with the responsible job of ecting the Rare Metal Section and then the fice of Rare Metals of the East Siberian Geo- gical Trust and East Siberian Geological Re- arch Institute in Irkutsk. That was the itical period of setting up the mineral base of rare metal industry in this country, and O. D. Levitskiy played an important part in its creation. Between 1936 and 1938, he held the no less responsible position of Chief Geologist for the East Siberian Division of the All-Union Exploration Organization for Rare Metals. After that he was engaged as senior scientist by the former Institute of Geologic Sciences, the U. S. S. R. Academy of Sciences, in Moscow. During the harsh years of the Great Patriotic War, O. D. Levitskiy, now an outstanding expert, was drafted for the Committee on Geology and the U S. S. R. Sovnarkom, where he directed the study of rare metals. In 1946, he returned to the Institute of Geological Sciences and organized a number of scientific studies within the frame- work of the East Siberian Expedition, of which he was head. He defended his Doctor's thesis in 1946 and was awarded the Stalin Prize, First Class. He was elected Corresponding Member of the Academy of Sciences, U. S. S. R., in 1953. In 1956 he was appointed Superintendent of the Division of Endogenetic Ore Deposits, Institute of the Geology of Metals (I. G. E. M.), Academy of Sciences, U. S. S. R., at which position he re- mained to the end of his life.

The scope of field studies by O. D. Levitskiy was determined by his interest in the geology of tungsten and tin. He worked in the rigorous marginal regions of Siberia, east of the Baykal meridian, also in the eastern Transbaykal region, the Far East and extreme Far East, Inner Mongolia, Kamchatka, and the Kuriles; he also visited the Altay and Middle Asia.

His first scientific work on the control of optic constants was published in 1929, while he was a student. This was followed by a series of other works, expert opinions, and consultation reports on the geology of rare minerals in the eastern U. S. S. R. Some of them have been published; the others, perhaps just as important, were used by the author in exploration for and evaluation of numerous ore deposits.

The trend and style of the scientific studies of O. D. Levitskiy are best reflected in his well- known monograph on the geology of West Trans- baykalian tungsten deposits, which was his Doctor's thesis. Here, the problems of the

[1] Oleg Dmitrievich Levitskiy, pp. 110-111.

spatial distribution, and features of the composition and structure of various rare metal deposits are considered against the background of an excellent description of this most interesting ore province of the Soviet Union. Its eleven rare metal and tungsten deposits and fields are treated with great skill and discrimination, in abundant detail revealing their most essential geologic and mineralogic features. Having evaluated the current theories on the origin of high-temperature hydrothermal deposits, O. D. Levitskiy presents a new treatment of this subject. He differentiates three types of mineralizing magmatic solutions, by the degree of their concentration; he traces the path of these solutions through fractures "gradually developed" by tectonic deformations; and he identifies the nature of interactions between the magmatic solutions and lateral rocks, thus formulating the first native approach to the geology and geochemistry of greisens. He voices the bold concept of a possible opening of veins during mineralization, as the result of an "active penetration of the magmatic solutions themselves." He skillfully discriminates between the vein filling and replacement processes in the general course of mineralization. He stresses the feasibility of forming quartz veins out of viscous colloidal solutions, basing his conclusions on theoretical premises as well as on the convincing observations which have since become standard arguments for a hydrothermal origin of colloidal mineralization.

Another, and no less important work of O. D. Levitskiy is the chapters in a book on the geology of tin, edited by S. S. Smirnov who had a high opinion of the scientific qualifications of O. D. Levitskiy. In that compendium, Levitskiy tin-ore deposits, with a detailed description of cassiterite-quartz formations. He identifies four types of tin deposits: greisen, topaz, feldspathic, and quartz. O. D. Levitskiy returned to the idea of endogenetic colloidal mineralization, in 1953, in an interesting essay for a compendium on fundamental problems in the theory of magmatic ore deposits.

In his last years, O. D. Levitskiy was absorbed in the study of primary zonation in tin veins, its causes, and applications in prospecting for such deposits.

The excellence of his scientific study had its roots in the broad scope of his geologic interest and his skill in perceiving the points of his particular interest, in the multiplicity of geologic phenomena. On the other hand, the results of his studies, aside from their importance in the geology of rare metals, have substantially influenced the progress of general geology.

O. D. Levitskiy was most closely connected with the field exploration and mining geology of rare metal deposits in the eastern part of our country. He accomplished much as a consultant and expert; he was always available to local field geologists with whom he studied maps and cross sections, and even assisted them in microscopic work. He initiated and organized a number of conferences. Quite recently, in 1958, he presided over the All-Union conference on methods of exploration for, and study of, endogenetic buried ore bodies. This conference has contributed much to the theory of mineralization and to mining practice.

For his scientific and practical accomplishments, O. D. Levitskiy was awarded the Order of the Toilers' Red Banner, Order of Red Star, and medals.

The high regard of Soviet geologists, particularly the mining geologists, for the ability and accomplishments of O. D. Levitskiy is a monument to his life and work.

REVIEWS AND DISCUSSIONS

"NEOMOBILISM" AND REGIONAL GEOTECTONICS[1, 2]

by

P. N. Kropotkin

. Kraus' "History of the Development of
:ontinents and Oceans", published in the
R. (East Germany) and recently put on
in the U. S. S. R., is a survey of the re-
l tectonics of the continents and oceans,
en from the point of view of neomobilism,
oretical trend which has become in the
decade leading, if not dominant, abroad.
nterest in neomobilism has grown as a
lt of the most recent geologic and geo-
cal studies. Several symposia have been
shed on continental drift and the migration
e poles [36, 37].

eologic studies of a number of regions have
nstrated the great importance and magni-
of lateral faulting, with movements of as
as 100 to 400 km (Scotland, California,
Zealand, the Pacific) [4]. Recent lateral
ments along certain faults have been
nstrated by geodetic observations. The
of South America and Africa has revealed
nd striking similarities, not only in the
ture of their sedimentary mantle but in
recambrian basement as well [24, 32],
an analysis of Cretaceous paleogeography
llowed the tracing of initial stages of
on in the network of faults along which the
tic trough appears to have developed [30].

avimetry and seismic sounding have
ly demonstrated the absence of continental
and its granite layer (i. e., the folded
nent) in deeper reaches of this trough[3]

eomobilizm" i regional'naya geotektonika,
2-116.

view of E. Kraus', Die Entwicklungs-
chte der Kontinente und Ozeane. Akademie-
;, Berling, 1959.

:h concepts of the structure of the oceanic
have not been supported by direct evidence,
. Editorial Board.

and have exposed the inconsistency of the hypothesis of submerged "intermediate continents" in the Atlantic and Indian Oceans [12, 13]. These features of oceanic structure, along with the fact that the assorted folded and platform structures of adjacent continents are cut off at margins of oceanic troughs, have also been noted by Soviet tectonists, in the last decade [9, 14, 16, 21].

Deep seismic troughs have always aroused interest; many authors regard them as modern geosynclines (the Kurile-Kamchatka trough, etc.). Seismic sounding and a study of their relief and associated major negative isostatic gravity anomalies have led to a recent concept that these troughs, too, were caused by a stretching and thinning of the crust; i. e., by lateral movements [17, 22]. Finally, the study of paleomagnetism, or the residual magnetism in rocks, has provided additional proof of mobilism or "continental drift" [10, 19, 36].

Neomobilism is a theory which interprets the horizontal displacement of continental blocks, not as "free drift" over a plastic mantle, induced by some unknown outside forces, as A. Wegener had it, but rather as a result of the very same horizontal and vertical movements in subcrustal matter, which are manifested in deep-focus earthquakes, in disturbance of isostatic equilibrium, etc. According to this concept, the movement of subcrustal masses, somewhat reminiscent of deepseated currents, carries along the lighter crustal material, piling it up in folds and overthrusts at places where these currents meet and flow downward (as in zones of deep-focus earthquakes along the Pacific periphery); stretching and breaking it up, and spreading it about, where the currents rise and flow laterally [5].

Granted the speculative nature of such a concept, it must be admitted that stress analysis by the A. V. Vvedenskaya and H. Honda, for the earthquake centers, suggests the presence of horizontal compression and tension, as if corroborating the heterogeneous nature of deformation, in accordance with the "subcrustal currents" hypothesis. Horizontal

compression has been observed in the Hindu kush (at a depth of 200 km) and the Japanese and Aleutian arcs (at less than 60 km), with horizontal tension in the Baykal graben zone (L. M. Balakina, oral communication; see also [2]).

The neomobilism concept does away with N. S. Shatskiy's objections to the Wegener hypothesis [20]. As pointed out by Ye. N. Lustich, the epeirophoresis hypothesis; i. e., a lateral shift of the continents, cannot be dismissed in the analysis of possible causes for tectonic deformations and the origin of the oceans. "To be sure, the classic theory of mobilism, postulating a sial crust gliding over a plastic substratum, has been repudiated. However, the assumption of a horizontal displacement of entire blocks of the sclerosphere, instead of the crust alone, eliminates most of the objections to this hypothesis. This concept of "neomobilism" is best associated with that of convection currents within ghe crust. It should be noted, however, that the convection hypothesis itself faces a number of difficulties which have not been overcome, so far. Perhaps it should be modified, by assuming a differentiation of matter rather than temperature variations as the cause of the density change" [12].

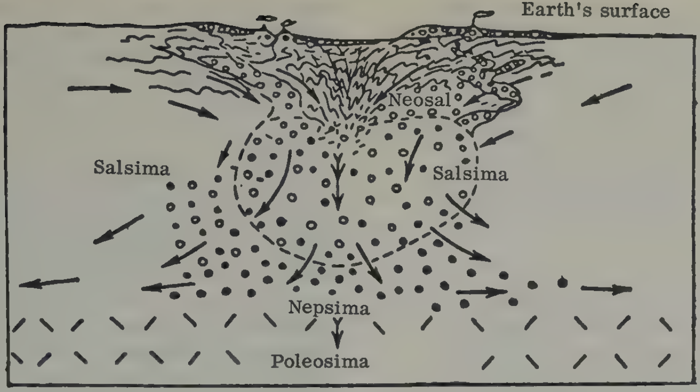
Reviewing this book by such an outstanding theoretician and expert in the geology of Europe as E. Kraus affords an opportunity to acquaint the reader with modern trends in geotectonics, abroad, and to demonstrate that the concept of horizontal crustal movements is supported by regional geologic data and explains the basic regularities in the development of geosynclines and folded provinces of the continents and oceans.

E. Kraus is the author of well-known works on Alpine geology and on the comparative tectonics of folded provinces [34], as well as of a number of works developing his theory of subcrustal currents [7]. In the book under review, he makes use of his voluminous material; he also presents a fairly objective exposition of the latest works and views of other authors, including A. D. Arkhangel'skiy, V. A. Obruchev, N. S. Shatskiy, and other Soviet geologists. He also presents a simplified version of the 1956 tectonic map of the U. S. S. R. The book is slanted toward a wide circle of readers, both professional geologists and those interested in geology for a broader scientific background, and is well written, with many specific examples and illustrations. It reflects the present status of West European science and touches upon various problems in tectonics, stratigraphy, volcanism, and geophysics, related to the growth of the continents in the process of folding, their breaking up in the formation of secondary oceanic troughs, and the development of the crust as a whole.

The book is in three parts. Part One is a brief presentation of the most important theories of the origin of the earth, and the principal geotectonic hypotheses: the contraction theory, the "tetrahedral" earth, epeirophoresis according to Wegener and its paleoclimatic and geologic substantiations, the R. Schtaub theory of continental drift from the pole to the equator, and the O. Ampherer theory of subcrustal currents which suggests the causes for major horizontal displacements of crustal blocks. It exposes the major fallacies of the contraction theory, its failure to explain the tension structures, also the uneven distribution of folded zones over the earth's surface, the thermal equilibrium of the earth, etc. It stresses, with references to Soviet studies, differences in orogenic phases and cycles, in provinces gravitating toward the Atlantic and Pacific.

Part Two deals on the whole with regional tectonics of the continents and oceans, considered with an historical approach; this is the gist of the work. Before undertaking such analysis, E. Kraus presents the principal geophysical data on the structure of the crust, and the main conclusions on the geosynclinal theory. He designates as salsima the so-called basaltic or intermediate crustal layer, contrasting it with both the granitic (sal or sial) and ultrabasic (sima) substrata. According to him, a differentiation of the salsima leads to the fractionation of granite magma ("neosal") which then rises and increases the volume of the granite layer. Salsima material, rid of these light derivatives, forms new ultrabasic bodies ("neosima"), heavier than either the salsima or the upper sima layers. The submerged "neosima" generates subcrustal currents flowing to these differentiation zones and forming the typical two-sided folded orogenic structure over them. Crustal material appears to be sucked in from both sides to the axial orogenic zones, which become a meeting place for the descending branches of subcrustal currents produced by convection and gravity differentiation (Figure 1). In this concept, all thrusts are caused by the framework blocks thrust under a growing folded structure; it also explains the overturning of folds away from the orogenic axis, on either side of it ("vergency"), as well as the migration of folding away from the axes of anticlinoria and toward their periphery, marginal troughs, and intrageosynclines.

E. Kraus identifies three stages in the development of a geosyncline: 1) the early stage, characterized by extension and thinning of the crust, a subsidence of its surface, and the flow of basic lava of the so-called "initial magmatism" of Stille (ophiolitic formations, etc.); 2) deep orogeny, subdivided in turn into an early substage, largely pelagic; and a later one or flysch; 3) high orogeny, with the formation of highlands and troughs filled with molasse. These views are similar to those of the N. S. Shatskiy school with its theory of formations. In this



Differentiation of the suborogenic hearth, with a two-sided structure (the hearth is outlined with dashes).

The structure of an orogeny is related to a downward movement of its roots (feathered arrow); salsima differentiation products rise up (neosal, granitic plutonic bodies, subsequent acid to intermediate volcanism, designated by circles) and descend (neosima, designated by dots), to generate subcrustal currents (hypotheon).

i, according to E. Kraus, continental areas extended as the geosynclines are closed up.

The author illustrates this process of continental growth with examples from the Pre-brian Baltic shield; Caledonian, Variscian, Alpine rocks of Europe; structures of the can platforms and its accretions in the hwest (Atlas) and the south (Cape system); ctures in Hindustan, Australia; folded belts ndonesia and New Guinea; and of South and h America with their folded belts in the (Andes, Rocky Mountains, young geosyn-es of the Pacific coast) and in the east alachians). The structural and historical larity of the Gondwanaland segments is hically illustrated by examples from the t recent literature. The development of and of the system of folded belts about the sian, Siberian, and Chinese platforms is ribed in considerable detail, largely from atest Soviet and Chinese sources. It is hically demonstrated that the growth of con-ntal massifs in the course of the develop- and closing of geosynclines is a process nically related to horizontal movements, to pression and tightening of the crust in enic zones, and to differentiation proc-s wherein the rising granite magma ents these zones, already consolidated ulting. Similarities in the rhythm of ement on either side of the Atlantic, as nst its difference from that prevailing in Thetis and the Pacific belt, leads E. Kraus e idea of mobility of crustal blocks and of pression replacing the tension throughout provinces. This is the conclusion reached N. Bubnoff in his essay on crustal moves [26].

The next part describes just as vividly the breaking up of these continental blocks and the formation of deep oceanic troughs between the now split asunder and separated or stretched out continental segments. These views are similar to those of B. Gutenberg and other foreign scientists [11, 18, 28, 29, 31]; E. Kraus supports them with voluminous illustrative material.

The geology of continental massifs fringing the Atlantic, Indian, and Arctic oceans, as well as the history of these basins, their relief and seismicity, afford the author an opportunity to demonstrate the secondary nature of all those three oceanic troughs, formed largely in the Mesozoic and Cenozoic. He regards the Pacific as a much older, or primary trough fringed with folded and volcanic belts which are associated with a deepseated crustal current flowing from west to east, and with a major "equatorial shift" traced as early as by G. Stille, from the Celebes to the islands of Fiji and Tonga. As previously explained by T. Kobayashi [33] and S. N. Bubnoff [26], the curve of the island arcs has been caused by their easterly drift, particularly well expressed in the progress of New Zealand and the Mariannas arc toward the central Pacific.

It should be noted that the latest geologic and gravity data for the Maritime Province, Korea, and Japan, as well as bathymetric and seismic data for the Japanese Sea bottom, support these views of E. Kraus, S. Bubnoff, and T. Kobayashi. The oceanic type of crustal structure, without the granite layer, has been discovered in deep reaches of the Sea of Japan [1]. The Proterozoic and late Hercinian folded structures are broken

off across their strike, at the northern rim of that trough and are continued only at its opposite side, in the Japanese islands.

E. Kraus associates the curves of the Antilles, South Sandwich, and South Orkney Islands with the same easterly drift and lateral faults. The most recent American studies by Menard, Rhode, and others, of lateral faults and rifts in the Antilles area, appear to support this theory.

Part Three of the book presents the principal conclusions. A synthesis of his material suggests to E. Kraus that the basis of tectonic processes lies in a gravity differentiation which produces magmatic melts of various compositions and densities, thus bringing forth subcrustal currents, the so-called hyporheon. Hyporheon currents result in the typical two-sided orogenic structure in geosynclinal provinces and in the gentle bulges in platforms. It is pertinent to note here that in the Caucasus, as cited by the opponents of the two-sided orogeny, there is movement in a number of places, on either side of the anticlinorial axis and away from it [3]. According to E. Kraus, the hyporheon convection is associated with a deeper and more uniform current, the bathyrheon. This deeper current flows almost everywhere from west to east and is manifest directly near the surface in the Pacific whose trough was initiated, according to him, as a result of the breakaway of the Moon, at an early stage in development of the Earth. Related to the bathyrheon movement is the "equatorial shift" mentioned above. The system of major latitudinal rifts recently discovered in the Pacific by Menard and others; is evidently associated with that; they have been found to be lateral faults with horizontal displacements up to 260 km [6, 38].

A number of objections can be advanced against these general conclusions of E. Kraus. In the light of modern cosmogonic theories, Pickering's hypothesis of the Moon coming out of the Pacific can hardly be accepted without reservations. The concept of Mesozoic and Cenozoic horizontal movements, interpreted in the light of the subcrustal movement hypothesis, suggests rather the existence of three immense provinces of the spreading-out of material: the Gondwana, Lawrasian, and Pacific, the latter embracing most of the Pacific ocean. It also suggests a mass movement toward the periphery of these provinces; i. e., to the Thetis and Pacific ring geosynclines between them. Still, one cannot categorically reject the possibility of diversified horizontal and vertical movements at different levels of the crust and at different "stories" of its differentiation. Evidence of horizontal displacements of electrically charged masses, near the earth core, and reminiscent of the bathyrheon, westward rather than eastward, is presented by the so-called "westerly drift" of the earth's magnetic field and of the centers of secular changes in its intensity, as described in all modern texts on terrestrial magnetism [23].

This book by E. Kraus will draw geologists' attention to the problem of horizontal movements, hitherto neglected in Soviet literature. Therein lies its main value. However, subcrustal movements of the type postulated by the author are not necessarily implied by the surface data. The heterogeneous horizontal movements can be interpreted in other ways, such as the pulsation hypothesis of M. A. Usov, V. A. Obruchev, and W. Bucher [8, 15, 27]. This hypothesis relates the folding to transverse compression of geosynclinal belts, during the earth's contraction phases; and the formation of grabens and genetically related troughs (apparently including the "secondary" oceanic troughs with their crust stretched or torn apart), on earth's expansion phases. Thus, the pulsation hypothesis postulates a differential reaction of the various tectonic zones to alternating compression and tension, with a corollary of considerable displacement of crustal blocks from zones of extension to those of compression, i. e., to the incipient folded zones.

REFERENCES

1. Andreyeva, I. V., and G. V. Udintsev, Stroyeniye dna Yaponskogo morya po dannym issledovaniy ekspeditsii na "Vityaze". [THE JAPANESE SEA-BOTTOM STRUCTURE FROM DATA OF THE VITYAZ EXPEDITION]: Izv. Akad. Nauk SSSR, ser. geol., no. 10, 1958.

2. Balakina, L. M., O raspredelenii napryazheniy, deystvuyushchikh v ochage zemletryaseniy severo-zapadnoy chasti Tikhogo okeana. [DISTRIBUTION OF STRESSES ACTIVE IN THE NORTHWESTERN PACIFIC EARTHQUAKE CENTER]: Izv. Akad. Nauk SSSR, ser. geofix., no. 11, 1959.

3. Vardanyants, L. A., Tektonicheskaya karta Kavkaza v masshtabe 1:1 000 000. Ob"yasnitel'naya zapiska. [TECTONIC MAP OF THE CAUCASUS, 1:1,000,000. LEGEND]: Gosgeoltekhizdat, 1955.

4. Vellman, G. V., Chetvertichnaya tektonika Novoy Zelandii. [QUATERNARY TECTONICS OF NEW ZEALAND]: In the collection, "Zhivaya tektonika". Izd-vo in. lit., 1957.

5. Vnutreniyeye stroyeniye Zemli. [INTERIOR STRUCTURE OF THE EARTH]: Izd-vo in. lit., 1949.

6. Zhivago, A. V., and G B. Udintsev,

Sovremennyye problemy geomorfologii dna okeanov i morey. [CURRENT PROBLEMS IN MORPHOLOGY OF THE BOTTOM OF SEAS AND OCEANS]: Izv. Akad. Nauk SSSR, ser. geogr., no. 1, 1960.

7. Kraus, Ye., O kharaktere noveyshikh dvizheniy v Al'pakh. [THE MOST RECENT MOVEMENTS IN THE ALPS]: In the collection, "Zhivaya tektonika". Izd-vo in. lit., 1957.

8. Kropotkin, P. N., Osnovnyye problemy energetiki tektonicheskikh protsessov. [MAIN PROBLEMS IN THE POWER OF TECTONIC PROCESSES]: Izv. Akad. Nauk SSSR, ser. geol., no. 5, 1948.

9. Kropotkin, P. N., Proiskhozhdeniye materikov i okeanov. [ORIGIN OF THE CONTINENTS AND OCEANS]: Priroda, no. 4, 1956.

0. Kropotkin, P. N., Znacheniye paleomagnetizma dlya stratigrafii i geotektoniki. [VALUE OF PALEOMAGNETISM IN STRATIGRAPHY AND GEOTECTONICS]: Byul. Mosk. o-va ispyt. prirody, Otd. geol., t. 33, vyp. 4, 1958.

1. Li Sy-guan, Geologiya Kitaya. [GEOLOGY OF CHINA]: Izd-vo in. lit., 1952.

2. Lyustikh, Ye. N., O gipotezakh talassogeneza i glybakh zemnoy kory. [THE THALASSOGENESIS HYPOTHESES AND CRUSTAL BLOCKS]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 11, 1959.

3. Magnitskiy, V. A., K voprosu o proiskozhdenii i putyakh razvitiya kontinentov i okeanov. [ORIGIN AND DEVEVELOPMENT OF THE CONTINENTS AND OCEANS]: Vopr. kosmogonii, vyp. 6, 1958.

4. Muratov, M. V., Problema proiskhozhdeniya okeanicheskikh vpadin. [ORIGIN OF OCEANIC TROUGHS]: Byul. Mosk. o-va ispyt. prirody, Otd. geol., t. 32, vyp. 5, 1957.

5. Obruchev, V. A., Pul'satsionnaya gipoteza geotektoniki. [THE PULSATION THEORY OF GEOTECTONICS]: Izv. Akad. Nauk SSSR, ser. geol., no. 1, 1940.

6. Pavlovskiy, Ye. V., O nekotorykh obshchikh zakonomernostyakh razvitiya zemnoy kory. [CERTAIN GENERAL REGULARITIES IN THE DEVELOPMENT OF THE EARTH'S CRUST]: Izv. Akad. Nauk SSSR, ser. geol., no. 5, 1953.

17. Uerzel, Dzh. L., and G. L. Sherbet, Interpretatsiya anomaliy sily tyazhesti na osnovanii standartnykh kolonok zemnoy kory dlya okeanov i materikov. [INTERPRETATION OF GRAVITY ANOMALIES FROM STANDARD STRATIGRAPHIC COLUMNS OF THE CRUST IN OCEANS AND CONTINENTS]: In the book, "Zemnaya kora". Izd-vo in. lit., 1957.

18. Kholms, A., Osnovy fizicheskoy geologii. [PRINCIPLES OF PHYSICAL GEOLOGY]: Izd-vo in. lit., 1949.

19. Khramov, A. N., Paleomagnitnaya korrelyatsiya osadochnykh tolshch. [PALEOMAGNETIC CORRELATION OF SEDIMENTARY SECTIONS]: Tr. Vses. neft. n.-i. geol.-razv. in-ta, vyp. 116, 1958.

20. Shatskiy, N. S., Gipoteza Vegenera i geosinklinali. [WEGENER'S HYPOTHESIS AND THE GEOSYNCLINES]: Izv. Akad. Nauk SSSR, ser. geol., no. 4, 1946.

21. Sheynmann, Yu. M., Platformy, skladchatyye poyasa i razvitiye struktur Zemli. [PLATFORMS, FOLDED BELTS, AND THE DEVELOPMENT OF TERRESTRIAL STRUCTURES]: Tr. Vses. n.-i. in-ta zolota i redkikh met., vyp. 1, Magadan, 1959.

22. Yuing, M., and B. Khizen, Topograficheskiye dannyye o zhelobe Puerto-Riko. [TOPOGRAPHIC AND GEOPHYSICAL DATA ON THE PUERTO RICO TROUGH]: In the book, "Zemnaya kora". Izd-vo in. lit., 1957.

23. Yanovskiy, B. M., Zemnoy magnetizm. [TERRESTRIAL MAGNETISM]: M., 1953.

24. Beurlen, K., La paléogéographie du continent de Gondwana. Cong. Géol. Intern. Comptes Rendus de la IX session. Alger, 1952, fasc. 15, 1954.

25. Bubnoff, S., Die Tektonik Japans und der Bau des pazifischen Raumes von Ostasien. Naturwissenschaften, Bd. 30, H. 38-39, 1942.

26. Bubnoff, S., Das Bewegungsbild der Erdrinde. Z. Dtsch. geol. Ges., Bd. 100, 1950.

27. Bucher, W. H., The deformation of the Earth's Crust. Bull. Geol. Soc. America, vol. 50, no. 3, 1939.

28. Du Toit, A. L., Our wandering continents. 2-d ed., London, 1957.

29. Goguel, J., Traité de tectonique, Paris, 1952.

30. Grabert, H., Zur Tektogenese Nordost-Brasiliens. Z. Dtsch. geol. Ges. Bd. III, Teil. 3, 1959.

31. Gutenberg, B., Verschiebung der Kontinente, eine kritische Betrachtung. In the book, Geotektonisch. Symposium zum Ehre H. Stille, Stuttgart, 1956.

32. Ebert, H. Beitrag zur Gliederung des Präkambriums in Minas Gerais. Geol. Rundschau, Bd. 45, no. 3, 1957.

33. Kobayashi, T., Tectonic development of Korea. Congrès Géologique intern. Comptes Rendus de la XIX session., Alger, 1952. Sect. XIII, fasc. XIV, Alger, 1954.

34. Kraus, E., Vergleichende Baugeschichte der Gebirge. Akademie-Verlag, Berlin, 1951.

35. Runcorn, S. K., Rock Magnetism. Science, vol. 129, no. 3355, 1959.

36. Symposium "Continental drift". Hobart, University of Tasmania, Geol. dep., 1958. Ref. in Geophys.-Abstracts, vol. 176, 1959.

37. Symposium on polar wandering and continental drift. J. Alberta Soc. Petrol. Geolog., vol. 6, no. 6-7, 1958. Ref. in Geophys. Abstracts, vol. 176, 1959.

38. Vacquier, V., Measurement of horizontal displacement along fault in the ocean floor. Nature, vol. 183, no. 4659, 1959.

Received, 17 June 1960

BIBLIOGRAPHY

OLOGIC LITERATURE RECEIVED IN THE BRARY OF THE SECTION OF GEOLOGIC ND GEOGRAPHIC SCIENCES, ACADEMY SCIENCES, U. S. S. R., FOR MARCH 1961

A. Articles in Periodicals

Abramovich, Ye. L., Opyt ritmostratigraficheskogo raschleneniya sredne- i verkhnedevonskikh otlozheniy Pritashkentskogo rayona. [RHYTHMIC STRATIGRAPHIC DIFFERENTIATION OF MIDDLE AND UPPER DEVONIAN DEPOSITS IN THE TASHKENT REGION]: Uzb. geol. zh., no. 6, 1960.

Avanis'yan, G. M., Novyye dannyye o tektonike karbona Donskoy Luki (v svyazi s perspektivami razvitiya dobychi gaza). [NEW DATA ON CARBONIFEROUS TECTONICS IN THE DONSKAYA LUKA (DON BEND) IN CONNECTION WITH GAS PROSPECTS]: Novosti neft. i gazovoy tekhniki, no. 1.

Aver'yanov, A. G., Glubinnoye seysmicheskoye zondirovaniye v perekhodnoy zone ot Aziatskogo kontinents k Tikhomu okeanu v period MGG. [DEEP SEISMIC SOUNDING IN THE TRANSITIONAL ZONE FROM ASIA TO THE PACIFIC, IN CONNECTION WITH THE IGY]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 2.

Azhgirey, G. D., Dva geneticheskikh tipa geosinklinal'noy skladchatosti. [TWO GENETIC TYPES OF GEOSYNCLINAL FOLDING]: Vestn. MGU, ser. IV, geol., no. 6, 1960.

Azizbekov, Sh. A., Perm' yugo Malogo Kavkaza. [THE PERMIAN IN THE SOUTHERN PART OF LESSER CAUCASUS]: Doklady, Akad. Nauk AzerbSSR, t. 16, no. 9, 1960.

Azizbekov, Sh. A., Trias yugo Malogo Kavkaza. [THE TRIASSIC IN THE SOUTHERN PART OF LESSER CAUCASUS]: Doklady, Akad. Nauk AzerbSSR, t. 16, no. 10, 1960.

7. Ayzberg, R. Ye., Osnovnyye cherty stroyeniye Priamudar'inskoy chasti Yugo-Vostochnoy Turkmenii. [MAIN STRUCTURAL FEATURES OF THE AMU DAR'YA AREA OF SOUTHEASTERN TURKMENIA]: Geol. nefti i gaza, no. 2.

8. Arapov, V. A., Stratigrafiya effuzivnoý tolshchi verkhnego paleozoya severnoy chasti Zapadnogo Karamazara. [STRATIGRAPHY OF UPPER PALEOZOIC EXTRUSIVE SEQUENCE IN THE NORTH OF WESTERN KARAMAZAR]: Uzb. geol. zh., no. 6, 1960.

9. Aslanyan, P. M., Novyye dannyye o faunisticheskoy kharakteristike tsirenovykh peschanikov i gorizonta Keara-Molla Yugo-Zapadnoy Armenii. [NEW DATA ON THE FAUNA OF THE CYRENE SANDSTONES AND THE KEARA-MOLLA HORIZON IN SOUTHWESTERN ARMENIA]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

10. Baranova, Yu. P., K istorii razvitiya rel'yefa Nizhne-Anadyrskoy nizmennosti i okruzhayushchikh yeye gor v chetcertichnom periode. [HISTORY OF THE DEVELOPMENT OF RELIEF IN THE LOWER-ANADYRKA PLAIN AND SURROUNDING MOUNTAINS, IN THE QUATERNARY]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

11. Barsanov, G. P., et al., Mezhdunarodnyy geologicheskiy kongress v Kopengagene. [INTERNATIONAL GEOLOGICAL CONGRESS IN COPENHAGEN]: Vestn. MGU, ser. IV, geol., no. 6, 1960.

12. Barkhatov, B. P., and G. G. Mel'nik, Nizhniy paleozoy Pamira i Darvaza. [LOWER PALEOZOIC IN THE PAMIRS AND DARVAZ]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

13. Bidzhiyev, R. A., and Yu. I. Minayeva, K voprosu ob istochnikakh snosa v period formirovaniya nizhneyurskikh kontinental'nykh otlozheniy v Tsentral'noy Yakutii

(basseyn Amgi). [THE PROBLEM OF SOURCE BEDS FOR LOWER JURASSIC CONTINENTAL DEPOSITS IN CENTRAL YAKUTIA (AMGA BASIN)]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

14. Budanov, V. I., A. M. Meskhi, V. N. Volkov, and S. P. Kirillov, Ob epokhakh granitoidnogo magmatizma Pamira i Darvaza. [EPOCHS OF GRANITIC MAGMATISM IN THE PAMIRS AND DARVAZ]: Doklady, Akad. Nauk SSSR, t. 136, no. 3.

15. Viktorov, B. N., Vzaimootnosheniye strukturnykh elementov oblasti predgornogo progiba. [RELATIONSHIP OF STRUCTURAL ELEMENTS IN THE FOREDEEP AREA]: Geol. nefti i gaza, no. 2.

16. Voytkevich, G. V., and L. K. Anokhina, O vozraste nekotorykh kompleksov gornykh porod Krivorozhskogo zhelezorudnogo rayona. [THE AGE OF CERTAIN ROCK COMPLEXES FROM THE KRIVOY ROG IRON-ORE REGION]: Geokhimiya, no. 2.

17. Volodarskiy, R. F., Regional'nyye gravimetricheskiye issledovaniya vostochnykh rayonov Russkoy platformy. [REGIONAL GRAVIMETRIC STUDY OF EASTERN AREAS OF THE RUSSIAN PLATFORM]: Vestn. MGU, ser. IV, geol., no. 6, 1960.

18. Gerasimovskiy, V. I., A. I. Polyakov, and Ya. M. Feygin, Stroyeniye differentsirovannogo o kompleksa porod luyavritov-foyyaitov—urtitov Lovozerskogo massiva. [STRUCTURE OF DIFFERENTIATED ROCK COMPLEX LUJAURITES—FOYAITES—URTITES, FROM THE LOVOZERO MASSIF]: Doklady, Akad. Nauk SSSR, t. 136, no. 3.

19. Gorelik, A. Z., O vliyanii solyanykh struktur Pripyatskoy vpadiny na raspredeleniye gidrograficheskoy seti i nekotoryye dannyye ob ikh razvitii v mezokaynozoye. [THE EFFECT OF SALT STRUCTURES IN THE PRIPYAT TROUGH ON THE DISTRIBUTION OF THE HYDROGRAPHIC NETWORK, AND CERTAIN DATA ON THEIR DEVELOPMENT IN THE MESOZOIC AND CENOZOIC]: Doklady, Akad. Nauk BSSR, t. 5, no. 1.

20. Gorin, V. A., O mekhanizme sdvigovykh razryvov v depressionnykh zonakh. [MECHANISM OF LATERAL FAULTS IN SUBSIDED ZONES]: Doklady, Akad. Nauk AzerbSSR, t. 16, no. 9, 1960.

21. Gofshteyn, I. D., Karta neotektoniki Verkhnego Pridnestrov'ya. [NEOGEOTECTONIC MAP OF THE UPPER DNESTR REGION]: Doklady, Akad. Nauk SSSR, t. 136, no. 3.

22. Grudkin, K. A., and L. P. Polkanova, O sootnoshenii strukturnykh etazhey antiklinali Yuzhnyy Alamyshik. [RELATIONSHIP OF STRUCTURAL LEVELS IN THE SOUTH ALAMYSHIK ANTICLINE]: Geol. nefti i gaza, no. 2.

23. Dubinskiy, A. Ya., and L. A. Vardanyants, Skladchatyy fundament Yasenko-Leningradskoy antiklinal'noy polosy v Severo-Zapadnom Predkavkaz'ye. [FOLDED BASEMENT OF THE YASENSK-LENINGRAD ANTICLINAL BELT IN NORTHWESTERN PRE-CAUCASUS]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

24. Dudauri, O. Z., Verkhnemelovyye subvulkanicheskiye malyye intruzii Bolnisskogo rayona. [MINOR SUBVOLCANIC INTRUSIONS OF UPPER CRETACEOUS AGE IN THE BOLNIS REGION]: Soobshch. Akad. Nauk GruzSSR, t. 25, no. 5, 1960.

25. Zhirov, K. K., G. I. Shestakov, and I. B. Ivanov, K voprosu ob interpretatsii tsifr vozrasta po svintsovomu metodu. [INTERPRETATION OF AGE FIGURES OBTAINED BY THE LEAD METHOD]: Geokhimiya, no. 1.

26. Zhukova, Ye. A., K stratigrafii verkhnemelovykh otlozheniy Bukharskoy oblasti. [STRATIGRAPHY OF UPPER CRETACEOUS DEPOSITS IN THE BOKHARA PROVINCE]: Uzb. geol. zh., no. 6, 1960.

27. Zhurenko, Yu. Ye., K izucheniyu golotsenovykh tektonicheskikh dvizheniy Zapadnoy Bashkirii. [A STUDY OF HOLOCENE TECTONIC MOVEMENTS IN WESTERN BASHKIRIA]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

28. Zonenshayn, L. P., G. A. Kudryavtsev, and A. A. Mossakovskiy, Analiz paleozoyskikh geologicheskikh formatsiy vostoka Altaye-Sayanskoy oblasti i nekotoryye osobennosti yeye tektonicheskogo stroyeniya. [AN ANALYSIS OF PALEOZOIC FORMATIONS IN THE EASTERN PART OF THE ALTAY SAYAN PROVINCE, AND CERTAIN FEATURES OF ITS TECTONIC STRUCTURE]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

29. Isayev, D. I., Nekotoryye formy rel'yefa kak pokazateli sledov molodykh tektonicheskikh dvizheniy vo vnutrennem Tyan'-Shane. [SOME RELIEF FORMS AS EVIDENCE OF YOUNG TECTONIC MOVEMENTS IN INTERIOR TIEN-SHAN]: Izv. Kirgizsk. fil. Vses. geogr. o-va, vyp. 2, 1960.

Kasumov, K. V., K tektonike mestorozhdeniya Gryazevaya Sopka. [TECTONICS OF THE GRYAZEVAYA SOPKA DEPOSIT]: Doklady, Akad. Nauk AzerbSSR, t. 16, no. 10, 1960.

Kasumova, G. M., Opisaniye novogo vida sredneoligitsenovykh otlozheniy Azerbaydzhana. [A NEW TYPE OF MIDDLE OLIGOCENE DEPOSITS IN AZERBAYDZHAN]: Doklady, Akad. Nauk AzerbSSR, t. 16, no. 10, 1960.

Keller, B. M., Novyye dannyye po stratigrafii verkhnego proterozoya (rifeya, siniya). [NEW DATA ON THE STRATIGRAPHY OF THE UPPER PROTEROZOIC (RIPHEAN, SINIAN)]: Vestn. MGU, ser. IV, geol., no. 6, 1960.

Kovylin, V. M., Novyye dannyye o moshchnosti donnykh otlozheniy Indiyskogo okeana. [NEW DATA ON THE THICKNESS OF BOTTOM DEPOSITS IN THE INDIAN OCEAN]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

Koshlyak, V. A., O svyazi teplovogo polya Zapadno-Sibirskoy nizmennosti s rel'yefom doyurskogo fundamenta. [RELATIONSHIP OF WEST SIBERIAN THERMAL FIELD AND RELIEF OF THE PRE-JURASSIC BASEMENT]: Geol. nefti i gaza, no. 1.

Kruglyakova, G. I., Rezul'taty paleomagnitnykh issledovaniy po Ukrainskomu kristallicheskomu massivu i prilegayushchim rayonam. [RESULTS OF MAGNETIC STUDIES IN THE UKRAINIAN CRYSTALLINE MASSIF AND ADJACENT REGIONS]: Izv. Akad. Nauk SSSR, ser. geofiz., no. 2.

Lavrov, V. M., Geologicheskoye stroyeniye materikovoy otmeli zapadnogo poberezh'ya Yuzhnogo Sakhalina. [GEOLOGIC STRUCTURE OF THE CONTINENTAL SHOAL OFF THE WEST COAST OF SOUTHERN SAKHALIN]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

Lebedinskiy, V. I., and T. I. Dobrovol'skaya, Novyye dannyye o nizhnemelovom vulkanizme v Gornom Krymu. [NEW DATA ON LOWER CRETACEOUS VOLCANISM IN THE MOUNTAINOUS CRIMEA]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

Makashvili, R. I., O vozraste Bardadzorskogo intruziva. [THE AGE OF THE BARDADZOR INTRUSION]: Soobshch. Akad. Nauk GruzSSR, t. 25, no. 5, 1960.

Mamedov, T. A., O vozraste paradashskoy svity paleogenovogo kompleksa Nakhichevanskoy ASSR. [THE AGE OF THE PARADASH PALEOGENE FORMATION IN THE NAKHICHEVAN ASSR]: Doklady, Akad. Nauk AzerbSSR, t. 16, no. 10, 1960.

40. Mamedov, T. A., and O. D. Gamzayev, Predvaritel'nyye dannyye o prisutstvii nummulitovoy fatsii eotsena v verkhov'yakh r. Tutkhun (s. Asrik). [PRELIMINARY DATA ON THE PRESENCE OF THE NUMMULITIC EOCENE FACIES IN THE UPPER COURSE OF TUTKHUN RIVER]: Doklady, Akad. Nauk AzerbSSR, t. 16, no. 9, 1960.

41. Markova, L. G., and Yu. F. Shirokova, Sporovo-pyl'tsevyye kompleksy maastrikhtskikh otlozheniy Tymskoy skvazhiny 1-R. [SPORE POLLEN ASSEMBLAGES FROM MAASTRICHTIAN DEPOSITS OF TYM BOREHOLE]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

42. Miroshnikov, L. D., Struktura fundamenta severnoy chasti Zapadno-Sibirskoy nizmennosti i vozmozhnost' yego neftenosnosti. [BASEMENT STRUCTURE IN THE NORTH OF THE WEST SIBERIAN PLAIN AND ITS OIL PROSPECTS]: Geol. nefti i gaza, no. 1.

43. Mogilev, A. Ye., Paleogeograficheskiye osobennosti nakopleniya turneyskikh uglenosnykh otlozheniy vostochnogo sklona Yuzhnogo Urala. [PALEOGEOGRAPHIC FEATURES OF THE DEPOSITION OF TOURNAISIAN COAL MEASURES IN THE EAST SLOPE OF THE NORTHERN URALS]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

44. Moiseyenko, F. S., O zakonomernosti izmeneniya plotnosti porod dokembriya i paleozoya Tsentral'nogo Kazakhstana. [REGULARITIES IN THE DENSITY CHANGES OF PRECAMBRIAN AND PALEOZOIC ROCKS IN CENTRAL KAZAKHSTAN]: Geol. i geofix., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

45. Moskvitin, A. I., Sootnosheniye nadpoymennykh terras Volgi i drevnikh transgressiy Kaspiya s oledeneniyami. [RELATIONSHIP OF THE VOLGA ABOVE-FLOOD TERRACES, ANCIENT CASPIAN TRANSGRESSIONS, AND GLACIATION]: Doklady, Akad. Nauk SSSR, t. 136, no. 3.

46. Murav'yev, I. S., Stratigrafiya i fatsial'noye stroyeniye verkhnepermskikh otlozheniy v basseyne srednego techeniya Pechory. [STRATIGRAPHY AND FACIES STRUCTURE OF UPPER PERMIAN DEPOSITS IN THE MIDDLE PECHORA BASIN]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

47. Nagibina, M. S., and T. V. Molchanova, O strukturnom polozhenii mezozoyskikh granitov v Mongolo-Okhotskoy zone i prilegayushchikh rayonakh Stanovogo khrebta. [STRUCTURAL POSITION OF MESOZOIC GRANITES IN THE MONGOL-OKHOTSK ZONE AND ADJACENT AREAS OF THE STANOVOY RANGE]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

48. Nikolayev, V. A., and L. Ya. Provodnikov, Verkhnetazovskiy svod. [VERKHETAZOV ARCH]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

49. Obnatanov, S. T., and G. P. Tamrazyan, K voprosu ob izmenenii moshchnosti produktivnoy tolshchi antiklinal'noy zony Surakhany-Karachukhur-Zykh-Peschanyy. [CHANGES IN THE THICKNESS OF THE PRODUCTIVE INTERVAL IN THE SURAKHANY-KARACHUKHUR-ZYKH-PESCHANYY ANTICLINAL ZONE]: Doklady, Akad. Nauk AzerbSSR, t. 16, no. 9, 1960.

50. Pashaly, N. V., K voprosu formirovaniya turkyanskogo gorizonta v predelakh Azerbaydzhana. [ON THE DEVELOPMENT OF THE TURKYAN HORIZON WITHIN AZERBAYDZHAN]: Doklady, Akad. Nauk AzerbSSR, t. 16, no. 10, 1960.

51. Polikarpov, G. G., Rol' detritoobrazovaniya v migratsii strontsiya-90, tseziya-137 i tseriya-144. Opyty s morskoy vodorosl'yu Cystoseira barbata. [THE ROLE OF DETRITUS FORMATION IN THE MIGRATION OF STRONTIUM 90, CESIUM 137, AND CESIUM 144. EXPERIMENTS WITH MARINE ALGA CYSTOCEIRA BARBATA]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

52. Postnikov, D. V., Kharakter svyazi poristosti i pronitsayemosti kollektorov terrigennoy tolshchi devona Yugo-Zapadnoy Bashkirii. [RELATIONSHIP BETWEEN POROSITY AND PERMEABILITY OF TERRIGENOUS DEVONIAN RESERVOIR ROCKS IN SOUTHWESTERN BASHKIRIA]: Novosti neft. i gazovoy tekhniki, no. 1.

53. Prozorovich, E. A., O metodike obrabotki rezul'tatov izucheniya plotnosti glinistykh porod. [ANALYSIS OF THE RESULTS OF STUDY OF THE DENSITY OF ARGILLACEOUS ROCKS]: Geol. nefti i gaza, no. 2.

54. Salayev, S. G., O nesootvetstvii skladchatykh struktur oligotsen-miotsenovogo i pliotsenovogo kompleksov Kobystana. [THE LACK OF CONFORMITY BETWEEN OLIGOCENE-MIOCENE AND PLIOCENE FOLDED STRUCTURES OF KOBYSTAN]: Doklady, Akad. Nauk AzerbSSR, t. 16, no. 9, 1960.

55. Smirnov, A. V., Novyye dannyye o rasprostranenii morskogo triasa. [NEW DATA ON THE DISTRIBUTION OF THE MARINE TRIASSIC]: Novosti neft. i gazovoy tekhniki, no. 1.

56. Tazetdinov, A. Z., Nekotoryye dannyye iz istorii razvitiya nizhnepermskikh otlozheniy na territorii Tatarii. [SOME DATA ON THE DEVELOPMENT OF LOWER PERMIAN DEPOSITS IN TATARIA]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

57. Tarkov, A. P., O geologicheskoy prirode anomaliy sily tyazgesti Amuro-Bureinskogo mezhdurech'ya. [GEOLOGIC INTERPRETATION OF GRAVITY ANOMALIES IN THE AMUR-BUREYA WATERSHED]: Geol. nefti i gaza, no. 2.

58. Tverdokhlebov, V. A., O krupnom valoobraznom podnyatii v vostochnoy chasti Irkutskogo amfiteatra. [A LARGE SWELL-LIKE UPLIFT IN THE EASTERN PART OF THE IRKUTSK AMPHITHEATRE]: Doklady, Akad. Nauk SSSR, t. 136, no. 3.

59. Urupov. A. K., Yu. A. Byakov, and S. A. Shikov, O kartirovanii oblastey uvelichennoy moshchnosti terrigennoy tolshchi nizhnego karbona seysmicheskim metodom otrazhennykh voln. [MAPPING THE AREAS OF THE THICK LOWER CARBONIFEROUS TERRIGENOUS SEQUENCE BY THE REFLECTION WAVE METHOD]: Geol. nefti i gaza, no. 2.

60. Pamyati, N. V., Frolovoy. [TO THE MEMORY OF N. V. FROLOVA]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

61. Chudinov, Yu. V., O blokovom stroyenii Polyarnogo Urala. [BLOCK STRUCTURE OF POLAR URALS]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

62. Shablinskaya, N. V., K metodike tektonicheskogo rayonirovaniya fundamenta Zapadno-Sibirskoy nizmennosti po geofizicheskim dannym. [THE METHOD OF TECTONIC DIFFERENTIATION OF THE WEST SIBERIAN BASEMENT, BY GEOPHYSICAL DATA]: Geol. nefti i gaza, no. 1.

63. Sholpo, V. N., Strukturnyye osobennosti zony razvitiya polnoy skladchatosti Slantsevogo Dagestana. [STRUCTURAL FEATURES OF THE FULL FOLDING ZONE IN SLANTSEVYY DAGESTAN]: Doklady, Akad. Nauk SSSR, t. 136, no. 3

Tszyan Tszu-tsi, K voprosu ob intensivnosti treshchinovatosti v sloistykh karbonatnykh porodakh Dagestana. [THE INTENSITY OF FRACTURING IN STRATIFIED CARBONATE ROCKS OF DAGESTAN]: Vestn. MGU, ser. IV, geol., no. 6, 1960.

Pamyati akademika Nikolaya Sergeyevicha Shatskogo (1895–1960). [TO THE MEMORY OF ACADEMICIAN NIKOLAY SERGEYEVICH SHATSKIY (1895–1960)]: Vestn. MGU, ser. IV, geol., no. 6, 1960.

PALEONTOLOGIYA

Baranov, V. I., and L. M. Yataykin, Novaya nakhodka verkhneoligotsenovoy flory v Zapadnom Kazakhstane. [A NEW FINDING OF UPPER OLIGOCENE FOSSILS IN WESTERN KAZAKHSTAN]: Doklady, Akad. Nauk SSSR, t. 136, no. 3.

Baskovich, R. A., A. P. Vas'kovskiy, and A. A. Kalinin, Pervaya nakhodka rissvyurmskoy mezhlednikovoy flory v Podporozhnom rayone basseyna Kolymy. [THE FIRST FINDING OF RISS-WÜRM INTERGLACIAL FLORA IN THE PODPOROZHNYY (RAPIDS) AREA OF THE KOLYMA BASIN]: Kolyma, no. 2.

Kovaleva, N. P., Novyye dannyye o vidovom sostave brakhiopod nizhnepaleogenovykh otlozheniy Kryma (Bakhchisarayskiy rayon) i Zakavkaz'ya (Sukhumskiy rayon). [NEW DATA ON SPECIFIC COMPOSITION OF BRACHIOPODS FROM LOWER PALEOGENE DEPOSITS OF THE CRIMEA (BAKHCHISARAY AREA) AND TRANSCAUCASUS (SUKHUM REGION)]: Doklady, Akad. Nauk SSSR, t. 136, no. 3.

Kolesnikova, T. D., K poznaniyu tretichnoy flory Zaobskogo yara v Zapadnoy Sibiri. [CONTRIBUTION TO THE KNOWLEDGE OF TERTIARY FAUNA IN THE ZAOBSK (TRANSOB) CLIFFS, WEST SIBERIA]: Botan. zh. Akad. Nauk SSSR, t. 46, no. 1.

Neyburg, M. F., Novyye dannyye o morfologii Pleuromeia Corda iz nizhnego triasa Russkoy platformy. [NEW DATA ON THE MORPHOLOGY OF PLEUROMEIA CORDA FROM LOWER TRIASSIC OF THE RUSSIAN PLATFORM]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

Repina, L. N., O nakhodkakh olenellid v lenskom yaruse Batenevskogo kryazha. [FINDINGS OF OLENELLIDS IN THE LENA STAGE OF THE BATENEV RIDGE]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

Svanidze, Ts. I., O vozraste iskopayemoy flory listovatykh slantsev i uglenosnoy svity okriby. [THE AGE OF FOSSIL PLANTS FROM THE OKTIBA SLATES AND COAL MEASURES]: Soobshch. Akad. Nauk GruzSSR, t. 25, no. 5, 1960.

73. Sidyachenko, A. I., Opyt primeneniya variatsionnoy statistiki pri izuchenii Cyrtospirifer iz famenskikh otlozheniy khrebta Karatau. [APPLICATION OF VARIATION STATISTICS IN THE STUDY OF CYRTOSPIRIFER FROM FAMENNIAN DEPOSITS IN THE KARATAU RANGE]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

74. Troitskiy, S. L., Sovremennaya i iskopayemaya Macoma baltica na poberezh'ye morya Laptevykh. [THE LIVING AND FOSSIL MACOMA BALTICA ALONG THE LAPTEV SEA COAST]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

75. Chalyshev, V. I., Nakhodka triasovykh ryb i stegotsefalov v Severnom Priural'ye. [A FINDING OF TRIASSIC FISHES AND STEGOCEPHALIANS IN THE NORTH URAL REGION]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

76. Shishkin, M. A., Novyye dannyye o Tupilakosaurus. [NEW DATA ON TUPILAKOSAURUS]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

77. Yataykin, L. M., Flora i rastitel'nost' kinel'skogo vremeni v rayone nizhney Kamy. [KINEL FLORA IN THE LOWER KAMA REGION]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

PETROGRAFIYA, MINERALOGIYA, KRISTALLOGRAFIYA, GEOKHIMIYA

78. Averin, Yu. A., K voprosu o genezise chadakskikh zhil'nykh skarnov i karbonatov. [ORIGIN OF THE CHADAK VEIN SKARNS AND CARBONATES]: Uzb. geol. zh., no. 6, 1960.

79. Azimov, P. T., and L. D. Smorodinova, Otbor i obrabotka prob massivov na aktsessornyye mineraly. [SAMPLING AND PROCESSING OF ROCKS FOR ACCESSORY MINERALS]: Uzb. geol. zh., no. 6, 1960.

80. Bakirov, A. G., K geokhimii giperbazitov. [GEOCHEMISTRY OF ULTRABASIC ROCKS]: Geokhimiya, no. 1.

81. Bandurkin, G. A., O povedenii redkozemel'nykh elementov vo ftorsoderzhashchikh sredakh. [BEHAVIOR OF RARE-EARTH ELEMENTS IN FLUORINE-BEARING MEDIA]: Geokhimiya, no. 2.

82. Baranov, V.I., and N.A. Titayeva, Soderzhaniye urana, toriya, radiya i ioniya v chetvertichnykh otlozheniyakh doliny r. Leny. [CONTENT OF URANIUM, THORIUM, RADIUM, AND IONIUM IN THE LENA VALLEY QUATERNARY]: Geokhimiya, no. 2.

83. Batalov, A.B., and P.V. Pankrat'yev, Elementy-primesi v zhelezorudnykh skarnakh Irisu. [ADDITIVE ELEMENTS IN THE IRISU IRON-ORE SKARNS]: Uzb. geol. zh., no. 6, 1960.

84. Bogoroditskiy, K.F., Rol'vody v perenose khimicheskikh elementov na uchastkakh podzemnoy gazifikatsii ugley. [ROLE OF WATER IN THE TRANSFER OF CHEMICAL ELEMENTS IN UNDERGROUND GASIFICATION OF COALS]: Geokhimiya, no. 1.

85. Bonshtedt-Kupletskaya, E.M., Novyye mineraly. [NEW MINERALS]: X. Zap. Vses. min. o-va, ch. 90, vyp. 1.

86. Bulakh, A.G., V.V. Kondrat'yeva, and Ye.N. Baranova, Karbotsernait — novyy redkozemel'nyy karbonat. [CARBOCERNAITE, A NEW RARE-EARTH CARBONATE]: Zap. Vses. min. o-va, ch. 90, vyp. 1.

87. Vinogradov, A.P., O proiskhozhdenii veshchestva zemnoy kory. [ORIGIN OF CRUSTAL MATTER]: Soobshcheniye 1. Geokhimiya, no. 1.

88. Gerling, E.K., I.M. Morozova, and V.V. Kurbatov, O sokhrannosti radiogennogo argona v izmel'chennykh kaliysoderzhashchikh mineralakh. [PRESERVATION OF RADIOGENIC ARGON IN CRUSHED POTASSIUM MINERALS]: Geokhimiya, no. 1.

89. Germanov, A.I., Geokhimicheskiye i gidrodinamicheskiye usloviya vozniknoveniya epigenetichskoy uranovoy mineralizatsii v nefte-vodonosnykh gorizontakh. [GEOCHEMICAL AND HYDRODYNAMIC CONDITIONS OF THE APPEARANCE OF EPIGENETIC URANIUM MINERALIZATION IN PETROLIFEROUS WATER-BEARING HORIZONS]: Geokhimiya, no. 2.

90. Ginzburg, A.I., and O.D. Stavrov, O soderzhaniy redkikh elementov v kordiyeritakh. [CONTENT OF RARE ELEMENTS IN CORDIERITES]: Geokhimiya, no. 2.

91. Glagoleva, M.A , K voprosu o vliyanii solenosti basseyna na nakopleniye elementov v yego osadkakh. [THE EFFECT OF SALINITY OF A BASIN ON THE ACCUMULATION OF ELEMENTS IN ITS SEDIMENTS]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

92. Gorbunova, L.I., Raspredeleniye organicheskogo veshchestva vo fraktsiyakh glin raznogo mineral'nogo sostava. [DISTRIBUTION OF ORGANIC MATTER IN CLAYS OF VARIOUS MINERAL COMPOSITIONS]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

93. Grigor'yev, D.P., Argonity Karlovykh Var. [ARAGONITE FROM KARLOVY VARY]: Priroda, no. 1.

94. Grudinin, M.I., and A.I. Kuznetsova, O rasprostranenii nikelya, khroma i kobal'ta v gabbro-peridotitovykh porodakh basseyna r Tyi (Severnoye Pribaykal'ye). [DISTRIBUTION OF NICKEL, CHROMIUM, AND COBALT IN GABRRO-PERIDOTITE OF THE TYYA RIVER BASIN (NORTHERN BAYKAL REGION)]: Geokhimiya, no. 2.

95. Denisov, Ye.P., Novyye dannyye o bazal'takh Primorskogo kraya. [NEW DATA ON BASALT FROM THE MARITIME PROVINCE]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

96. Yeremenko, N.A., and V.L. Mekhtiyeva, Rol' mikroorganizmov v protsessakh fraktsionirovaniya stabil'nykh izotopov sery. [ROLE OF MICROORGANISMS IN THE FRACTIONATION OF STABLE SULFUR COMPOUNDS]: Geokhimiya, no. 2.

97. Zabarina, T.V , V.V. Lapina, and N.A. Minayeva, Raspredeleniye indiya v kassiterite, sfalerite i khal'kopirite Lifudzinskogo olovorudnogo mestorozhdeniya. [DISTRIBUTION OF INDIUM IN CASSITERITE, SPHALERITE, AND CHALCOPYRITE OF THE LIFUDZIN TIN-ORE DEPOSIT]: Geokhimiya, no. 2.

98. Zakrutkin, V.V., Ob anabarskikh psevdotakhilitakh i ikh vozraste. [ANABAR TACHYLYTES AND THEIR AGE]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

99. Zvyagintsev, O.Ye., Retsenziya na knigu "Problemy geokhimii". Vyp. 1. Izd. L'vovsk. un-ta, 1960. [REVIEW OF BOOK "PROBLEMS IN GEOCHEMISTRY". ISSUE 1, LVOV UNIVERSITY PUBLICATION, 1960]: Geokhimiya, no. 1.

100. Ivanov, V.V., and A.A. Rozbianskaya, Geokhimiya indiya v kassiterito-silikatno-sul'fidnykh rudakh. [GEOCHEMISTRY OF INDIUM IN CASSITERITE-SILICATE-SULFIDE ORES]: Geokhimiya, no. 1.

101. Ivanov, V.V., K geokhimii kadmiya v mestorozhdeniyakh Deputatskoy gruppy. [GEOCHEMISTRY OF CADMIUM IN THE

DEPUTATSKAYA GROUP OF DEPOSITS]: Geokhimiya, no. 2.

Ivanova, V. P., Termogrammy mineralov. [THERMOGRAMS OF MINERALS]: Zap. Vses. min. o-va, ch. 90, vyp. 1.

Karyakin, L. I., and A. T. Zelenskaya, Izmeneniye kvartsevogo porfira pri nagrevanii. [ALTERATION OF QUARTZ PORPHYRY IN HEATING]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

Kogarko, L. N., Usloviya obrazovaniya villiomita v nefelinovykh sayenitakh (Lovozerskiy massiv). [THE FORMATION CONDITIONS OF WILLIOMITE IN NEPHELINE SYENITE (LOVOZERO MASSIF)]: Geokhimiya, no. 1.

Koyava, V. S., K petrografii kislykh effuzivov basseyna r. Galidzga. [PETROGRAPHY OF ACID EXTRUSIVES IN THE GALIDZGA RIVER BASIN]: Soobshch. Akad. Nauk GruzSSR, t. 25, no. 5, 1960.

Kuznetsov, Ye. A., and Li Chzhao-lin, Dispersiya dvuprelomleniya, khimicheskiy sostav i struktura berillov. [BIREFRINGENCE DISPERSION, CHEMICAL COMPOSITION, AND STRUCTURE OF BERYL]: Vestn. MGU, ser. IV, geol., no. 6, 1960.

Kulish, Ye. A., Rannemezozoyskiye shchelochnyye granity yuga Aldanskogo shchita. [EARLY MESOZOIC ALKALIC GRANITES IN THE SOUTHERN PART OF THE ALDAN SHIELD]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

Lemmleyn, G. G., and P. V. Klevtsov, Sootnosheniya osnovnykh termodinamicheskikh parametrov dlya chasti sistemy $H_2O - NaCl$. [RELATIONSHIP OF PRINCIPAL THERMODYNAMIC PARAMETERS FOR A PORTION OF THE SYSTEM $H_2O - NaCl$]: Geokhimiya, no. 2.

Makarochkin, B. A., Pribaykal'skiy chevkinit. [THE BAYKAL REGION CHEVKINITE]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

Marakushev, A. A., and Yu. K. Polin, O raspredelenii galliya v mineralakh arkheyskikh metamorficheskikh porod Aldanskogo shchita. [GALLIUM DISTRIBUTION IN MINERALS FROM ARCHEAN METAMORPHICS OF THE ALDAN SHIELD]: Geokhimiya, no. 2.

Maslova, I. N., Ul'tramikrokhimicheskoye issledovaniye sostava zhidkoy i gazovoy faz dvukhfazovykh vklyucheniy kvartsev Volyni. [ULTRAMICROSCOPIC STUDY OF THE COMPOSITION OF THE LIQUID AND GASEOUS PHASES IN TWO-PHASE QUARTZ INCLUSIONS]: Geokhimiya, no. 2.

112. Miroshnichenko, L. A., and T. A. Veleshina, Selen i tellur v polimetallicheskikh mestorozhdeniyakh Tsentral'nogo Kazakhstana. [SELENIUM AND TELLURIUM IN POLYMETAL DEPOSITS OF CENTRAL KAZAKHSTAN]: Vestn. Akad. Nauk KazSSR, no. 1.

113. Mukanov, K. M., M. Z. Fursova, and M. K. Yanulova, Plattnerit iz zony okisleniya svintsovo-baritovogo mestorozhdeniya Karagayly. [PLATTNERITE FROM THE OXIDATION ZONE IN THE KARAGAYLA LEAD-BARITE DEPOSIT]: Vestn. Akad. Nauk KazSSR, no. 1.

114. Naumov, G. B., Nekotoryye fiziko-khimicheskiye osobennosti povedeniya urana v gidrotermal'nykh rastvorakh. [SOME PHYSICO-CHEMICAL FEATURES OF THE URANIUM BEHAVIOR IN HYDROTHERMAL SOLUTIONS]: Geokhimiya, no. 2.

115. Perel'man, A. I., Geokhimiya drevnikh landshaftov. [GEOCHEMISTRY OF ANCIENT LANDSCAPES]: Priroda, no. 1.

116. Petrov, V. M., and I. P. Zarevich, Daykovyye intruzii Unkurtashskogo rudoproyavleniya i osobennosti ikh stroyeniya. [DIKE INTRUSIONS IN THE UNKURTASH ORE DEPOSIT AND THEIR SPECIFIC STRUCTURAL FEATURES]: Uzb. geol. zh., no. 6, 1960.

117. Pecherskiy, D. M., Ob otbore obraztsov izverzhennykh gornykh porod dlya izucheniya ikh magnitnykh svoystv. [SAMPLING OF EXTRUSIVE ROCKS FOR THE STUDY OF THEIR MAGNETISM]: Kolyma, no. 2.

118. Popova, Z. D., Tsink v zone okisleniya plastovykh fosforitov mestorozhdeniya Sarysay. [ZINC IN THE OXIDATION ZONE OF SARYSAY STRATIFIED PHOSPHORITE]: Vestn. Akad. Nauk KazSSR, no. 1.

119. Rudnik, V. A., O geneticheskom razdelenii anatektoidnykh porod Bureinskogo khrebta na Dal'nem Vostoke. [GENETIC DIFFERENTIATION OF ANATAXITIC ROCKS IN THE BUREYA RANGE, THE FAR EAST]: Zap. Vses. min. o-va, ch. 90, vyp. 1.

120. Rundkvist, D. V., V. K. Denisenko, and N. Ye. Chistyakov, Ob usrednenıı khimicheskoho sostava porod pri

regional'no-kontaktovom metamorfizme. [NEUTRALIZATION OF THE CHEMICAL COMPOSITION OF ROCKS, IN REGIONAL-CONTACT METAMORPHISM]: Zap. Vses. min. o-va, ch. 90, vyp. 1.

121. Sardatov, S. S., Energiya svyazi i sikhrannost' radiogennogo argona v slyudakh. [THE BOND ENERGY AND PRESERVATION OF RADIOGENIC ARGON IN MICA]: Geokhimiya, no. 1.

122. Sviridenko, A. F., Metasomaticheskiye aplity v granitoidakh Zapadnogo Uzbekistana. [METASOMATIC APLITE IN GRANITIC ROCKS OF WESTERN UZBEKISTAN]: Uzb. geol. zh., no. 6, 1960.

123. Semenov, Ye. I., Khun Ven-sin, and T. A Kapitonova, O novom niobiyevom minerale baotite. [BAOTITE, A NEW NIOBIUM MINERAL]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

124. Slepnev, Yu. S., and L. L. Shanin, Absolyutnyy vozrast redkometal'nykh pegmatitov V. Sayana. [THE ABSOLUTE AGE OF RARE-METAL PEGMATITES FROM EAST SAYAN]: Geokhimiya, no. 1.

125. Smirnov, G. I., and A. D. Khar'kiv, Taumasit v kimberlitakh Yakutii. [TAUMASITE IN YAKUTIAN KIMBERLITE]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

126. Pamyati, L. L., Solodovnikovoy. [SOLODOVNIKOVA]: Zap. Vses. min. o-va, ch. 90, vyp. 1.

127. Sopko, P. F., V. I. Belyayev, and G. V. Zhilenkov, Nekotoryye dannyye o magmaticheskikh porodakh osnovnogo i ul'traosnovnogo sostava v yuzhnoy chasti Voronezhskoy oblasti i ikh metallogenicheskoye znacheniye. [A FEW DATA ON BASIC AND ULTRABASIC ROCKS IN THE SOUTHERN PART OF VORONEZHSKAYA OBLAST AND THEIR METALLOGENIC SIGNIFICANCE]: Doklady, Akad. Nauk SSSR, t. 136, no. 2.

128. Tikhonenkov, I. P., Ob odnom tipe poslemagmaticheskikh metasomaticheskikh protsessov v shchelochnykh massivakh. [A TYPE OF POSTMAGMATIC METASOMATIC PROCESS IN ALKALIC MASSIFS]: Doklady, Akad. Nauk SSSR, t. 136, no. 4.

129. Filippov, Ye. M., and G. A. Kuznetsov, Vozmozhnosti primeneniya metoda rasseyannogo beta-izlucheniya pri analize mineral'nogo syr'ya. [FEASIBILITY OF APPLYING DIFFUSED BETA-RADIATION IN THE ANALYSIS OF MINERAL RAW MATERIAL]: Geol. i geofiz. Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

130. Khitarov, N. I., Novyye dannyye po fazovym prevrashcheniyam vismuta, tseziya, talliya i bariya pri sverkhvysokikh davleniyakh. (K rabotam po sintezu almaza, granatov i drugikh mineralov). [NEW DATA ON THE PHASE TRANSFORMATION OF BISMUTH, CESIUM, THALLIUM, AND BARIUM AT SUPER-HIGH PRESSURES (IN THE SYNTHESIS OF DIAMOND, GARNET, AND OTHER MINERALS)]: Geokhimiya, no. 2.

131. Chukhrov, F.V., O zasedaniyakh Mezhdunarodnoy mineralogicheskoy assotsiatsii vo vremya 21 sessii Mezhdunarodnogo geologicheskogo kongressa. [MEETING OF THE INTERNATIONAL MINERALOGICAL ASSOCIATION DURING THE XXI SESSION OF THE INTERNATIONAL GEOLOGICAL CONGRESS]: Zap. Vses. min. o-va, ch. 90, vyp. 1.

132. Shafranovskiy, I. I., Kristallomorfologiya dvoynikov. [CRYSTALLOMORPHOLOGY OF TWINNING]: Zap. Vses. min. o-va, ch. 90, vyp. 1.

133. Shafranovskiy, I. I., and B. B. Zvyagin, V Mezhdunarodnyy kongress kristallografov. [THE INTERNATIONAL CONGRESS OF CRYSTALLOGRAPHERS]: Zap. Vses. min. o-va, ch. 90, vyp. 1.

134. Shmulevich, A. D., Rtut' v sul'fidakh iz osadochnykh mestorozhdeniy yugozapadnykh otrogov Gissara. [MERCURY IN SULFIDES FROM SEDIMENTARY DEPOSITS OF THE SOUTHWESTERN HISSAR PRONGS]: Uzb. geol. zh., no. 6, 1960.

135. Yakubov, D. Kh., Raspredeleniye rasseyannykh elementov v zone zheleznogo razloma (Kuraminskiy khrebet). [DISTRIBUTION OF DISPERSED ELEMENTS IN THE IRON FAULT ZONE (KURAMIN RANGE)]: Uzb. geol. zh., no. 6, 1960.

INDUSTRIAL MINERALS AND METHODS FOR THEIR EXPLORATION

136. Abdullayev, Kh. M., T. M. Voronin, O. I. Ismailov, and I. Kh. Khamrabayev, 75 let so dnya rozhdeniya vydayushchegosya issledovatelya rudnykh bogatstv Sredney Azii B. N. Nasledova. [THE 75TH BIRTHDAY OF B. N. NASLEDOV, AN OUTSTANDING STUDENT OF CENTRAL ASIAN ORES]: Uzb. geol. zh., no. 6, 19

Antropov, P. Ya., Oshibki teoreticheskiye neizbezhno vedut k oshibkam prakticheskim (Po povodu ryada statey I. O. Broda i M. F. Mirchinka). [ERRORS OF THEORY UNAVOIDABLY LEAD TO ERRORS IN PRACTICE (CONCERNING THE ARTICLES BY I. O. BROD AND M. F. MIRCHINEK)]: Geol. nefti i gaza, no. 1.

Ashirov, K. B., O geologicheskikh usloviyakh obrazovaniya Sadkinskogo asfal'titovogo mestorozhdeniya. [GENESIS OF THE SADKINO ASPHALTITE DEPOSIT]: Novosti neft. i gazovoy tekhniki, no. 1.

Babayev, A. G., L. G. Zhukovskiy, Ye. V. Lebzin, and Yu. V. Kayesh, Tipy skopleniy nefti i gaza v rayonakh Zapadnogo i Yuzhnogo Uzbekistana. [TYPES OF OIL AND GAS ACCUMULATIONS IN AREAS OF WESTERN AND SOUTHERN UZBEKISTAN]: Geol. nefti i gaza, no. 1.

Brod, I. O., O zadachakh sravnitel'noy otsenki perspektiv neftegazonosnosti krupnykh territoriy i otdel'nykh ploshchadey. [PROBLEMS IN COMPARATIVE EVALUATION OF OIL AND GAS PROSPECTS IN LARGE AND SMALL AREAS]: Novosti neft. i gazovoy tekhniki, no. 1.

Buyalov, N. I., et al., Metodika otsenki resursov prirodnogo gaza i nefti. [EVALUATION OF OIL AND GAS RESERVES]: Geol. nefti i gaza, no. 1.

Buyalov, N. I., O knige "Geologicheskoye stroyeniye i neftegazonosnost' Yakutskoy ASSR". [REVIEW OF BOOK "GEOLOGIC STRUCTURE AND OIL AND GAS IN THE YAKUTIAN ASSR"]: Geol. nefti i gaza, no. 2.

Vasil'yev, V. G., Resursy prirodnogo gaza v SSSR. [NATURAL GAS RESERVES IN THE USSR]: Novosti neft, i gazovoy tekhniki, no. 1.

Vedunova, N. K., and N. A. Koprova, Novyye dannyye k khimiko-bituminologicheskoy kharakteristike asfal'tita Sadkinskogo mestorozhdeniya. [NEW DATA ON CHEMICAL AND BITUMINOLOGIC CHARACTERISTICS OF ASPHALTITE IN THE SADKINO DEPOSIT]: Novosti neft. i gazovoy tekhniki, no. 1.

Velikovskiy, A. S., Razlichnyye tipy neftey i vozmozhnyye prichiny ikh obrazovaniya. [THE VARIOUS TYPES OF CRUDE OILS AND THE CAUSES OF THEIR FORMATION]: Geol. nefti i gaza, no. 1.

Velichko, A. V., Ob opredelenii polozheniya vodo-neftyanogo kontakta. [DETERMINING THE OIL-WATER CONTACT]: Geol. nefti i gaza, no. 2.

147. Gabrielyan, A. G., L. N. Rozanov, and R. B. Seyful'-Mulyukov, O burenii sverkhglubokikh skvazhin v Severnom Prikaspii. [DRILLING SUPER-DEEP TEST HOLES IN THE NORTH CASPIAN REGION]: Geol. nefti i gaza, no. 1.

148. Dement'yev, L. F., and V. I. Azamatov, Ob opredelenii sredney poristosti i neftenasyshchennosti pri podschete zapasov i proyektirovanii razrabotki. [DETERMINING THE AVERAGE POROSITY AND OIL SATURATION IN COMPUTING THE RESERVES AND IN DEVELOPMENT PLANNING]: Novosti neft. i gazovoy tekhniki, no. 1.

149. Deordiyev, Z. G., Opyt gazovogo karotazha posle bureniya skvazhin. [EXPERIMENT IN POST-DRILLING GAS LOGGING]: Novosti neft. i gazovoy tekhniki, no. 1.

150. Zerchaninov, I. K., K metodike issledovaniya neftyanykh skvazhin. [METHODS OF OIL WELL STUDY]: Geol. nefti i gaza, no. 1.

151. Kolganov, V. I., Rezul'taty analiza vodo- i neftenasyshchennosti kernov plasta B_2 Zol'nenskogo mestorozhdeniya. [RESULTS OF CORE ANALYSIS FROM HORIZON B_2, THE ZOL'NENSK FIELD, FOR WATER AND OIL SATURATION]: Novosti neft. i gazovoy tekhniki, no. 1.

152. Krutov, G. A., O roli galoidnogo protsessa v obrazovanii kontaktovo-metasomaticheskikh mestorozhdeniy. [PART OF THE HALOID PROCESS IN FORMING CONTACT-METASOMATIC DEPOSITS]: Vestn. MGU, ser. IV, geol., no. 6, 1960.

153. Li, K. A., Metodika vskrytiya i oprobavaniya produktivnykh gorizontov v razvedochnykh skvazhinakh Aktyubinskogo Priural'ya. [METHODS OF OPENING AND TESTING PRODUCTIVE HORIZONS IN WILDCAT WELLS OF THE AKHTYUBA URAL REGION]: Geol. nefti i gaza, no. 1.

154. Malakhov, A. A., K klassifikatsii strukturno-metallogenicheskikh ob"yektov mezo-kaynozoyskoy skladchatosti. [CLASSIFICATION OF STRUCTURAL METALLOGENIC OBJECTS IN MESOZOIC AND CENOZOIC FOLDING]: Uzb. geol. zh., no. 6, 1960.

155. Mel'nikov, A. M., and Ye. Voytovich, Ob usloviyakh zaleganiya nefti na Nurlagskoy ploshchadi i perspektivakh poiskovo-razvedochnykh rabot. [OCCURRENCE

OF OIL IN THE NURLAT AREA AND ITS EXPLORATION PROSPECTS]: Novosti neft. i gazovoy tekhniki, no. 1.

156. Minskiy, N. A., Ob izmeneniyakh teplovogo rezhima v neftenosnykh porodakh Vostochnoy Gobi. [CHANGES IN THE THERMAL REGIMEN OF PETROLIFEROUS ROCKS IN EAST GOBI]: Geol. nefti i gaza, no. 2.

157. Morozov, S. G., Kollektorskiye svoystva porod dosrednedevonskikh otlozheniy Zapadnoy Bashkirii. [RESERVOIR PROPERTIES OF PRE-MIDDLE DEVONIAN ROCKS IN WESTERN BASHKIRIA]: Novosti neft. i gazovoy tekhniki, no. 1.

158. Muromtsev, A. S., Gazovyye grifony. [SURFACE GAS SHOWS]: Priroda, no. 1.

159. Savadskiy, O. A., Novyy variant metallometricheskoy s"yemki ("magnitnaya mineralometriya"). [A NEW VARIANT OF METALLOMETRIC SURVEYING ("MAGNETIC MINERALOMETRY")]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

160. Sidorenko, S. F., Nekotoryye osobennosti rezul'tatov oprovaniya skvazhin. [CERTAIN SPECIFIC RESULTS OF WELL TESTING]: Geol. nefti i gaza, no. 1.

161. Sokolin, Kh. G., O prevrashchenii neftey v zalezhakh (na primere Stalingradskikh mestorozhdeniy). [ALTERATION OF CRUDE OIL IN SITU (IN THE STALINGRAD FIELDS)]: Novosti neft. i gazovoy tekhniki, no. 1.

162. Starobinets, I. S., and A. Z. Zebeleva, K kharakteristike prirodnykh gazov Zapadnogo Uzbekistana. [DESCRIPTION OF NATURAL GASES FROM WESTERN UZBEKISTAN]: Uzb. geol. zh., no. 1, 1960.

163. Tychinskiy, A. A., and V. I. Sotnikov, O mineralogicheskom sostave i genezise rud rtutnykh mestorozhdeniy Kurayskoy rudnoy zony v Gornom Altaye. [MINERAL COMPOSITION AND ORIGIN OF MERCURY-ORE DEPOSITS IN THE KURAYSK ORE ZONE, GORNYY ALTAY]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 1960.

164. Shevshenko, S. P., O pryamykh metodakh poiskov mestorozhdeniy nefti i gaza. [DIRECT METHODS OF SEARCH FOR OIL AND GAS]: Geol. nefti i gaza, no. 2.

165. Shcherbakov, Yu. G., Zakonomernosti zolotoorudeneniya v Severo-Vostochnom Altaye i smezhnykh rayonakh Kuznetskogo Alatau. [REGULARITIES IN GOLD MINERALIZATION IN NORTHEASTERN ALTAY AND ADJACENT REGIONS OF KUZNETSK ALATAU]: Geol. i geofiz., Sib. otd. Akad. Nauk SSSR, no. 12, 19[illegible]

166. Ezdrin, M. B., and A. M. Vel'kov, O vydelenii ob"yektov oprobovaniya v karbonatnykh porodakh paleozoya. [SELECTION OF TESTING OBJECTS IN PALEOZOIC CARBONATE ROCKS]: Novosti neft. i gazovoy tekhniki, no. 1.

HYDROGEOLOGY, ENGINEERING GEOLOGY

167. Berzina, L. K., Opyt opredeleniya shirin[illegible] zony vliyaniya pavodka reki na gruntovy[illegible] vody. [DETERMINING THE WIDTH OF THE FLOOD PLAIN ZONE AFFECTING GROUND WATER]: Doklady, Akad. Na[illegible] BSSR, t. 5, no. 1.

168. Dublyanskiy, V. N., Krasnaya peshchera. [THE RED CAVERN]: Priroda, no. 1.

169. Zhuravlev, M. V., K voprosu o solevom sostave vody Mingechaurskogo vodokhranilishcha. [SALT COMPOSITION O[illegible] WATERS IN THE MINGECHAUR WATE[illegible] STORAGE RESERVOIR]: Doklady, Aka[illegible] Nauk AzerbSSR, t. 16, no. 9, 1960.

170. Sukharev, G. M., O vodakh mezozoyskik[illegible] otlozheniy Kavkaza v svyazi s otsenkoy perspektiv neftegazonosnosti. [WATER IN THE CAUCASIAN MESOZOIC DEPOSITS, IN CONNECTION WITH THEIR OIL AND GAS PROSPECTS]: Geol. neft[illegible] i gaza, no. 2.

B. Articles in "Materials", Trudy", "Uchenyye Zapiski", and "Sborniki"

1. Voprosy geologii vostrochnoy okrainy Russkoy platformy i Yuzhnogo Urala. [Problems in the Geology of the Eastern Margin of the Russian Platform and Southern Urals]: 5, Ufa, 1960, 202 pp. Partial contents: Yakhimovich, V. L., Problems of the lower boundary of the Quaternary (Anthropogene), in the Bashkirian Pre-Urals; Dorofeyev, P. I., Pliocene flora of Bashkirian Pre-Urals; Nemkova, V. K., Spore-pollen descript[illegible] of Kinel deposits (in the Khabarovsk brown-coal field, Orenburg Oblast; Nemkova, V. K., Kinel floras along Ufa River; Kolesnikova, T. D., A new findi[illegible] of Neogene flora in the Bashkirian Pre-Urals; Chiguryayeva, A. A., Pliocene vegetation in the southeastern part of th[illegible] European USSR; Vakhrushev, G. V., Fi[illegible]ings of fish imprints in Pliocene deposit[illegible] of Bashkirian Pre-Urals; Dorofeyev, P.

Pleistocene floras of the North Caspian Region; Chiguryayeva, A. A., Ye. A. Skidanova, and V. L. Yakhimovich, Data on the Middle Pleistocene flora in the southeastern part of the European USSR; Chiguryayeva, A. A., Microspores from a horizon with bones of a wild boar (Sus scrofa Z.), by the Minueshta Creek, Western Bashkiria; Voronina, I. G., Identification of Pleistocene Alder, by its pollen; Yakhimovich, N. N., Finding of Parelephas trogontherii (Pohl) on Sukhaila River; Shokurov, A. P., and O. N. Bader, A Paleolithic site on Belaya River; Kirilina, S. V., Mollusks from lower terraces of Bashkirian Pre-Urals; Vakhrushev, G. V., The origin and age of certain boulder-pebble deposits in the Bashkirian Pre-Urals; Yakhimovich, V. L., The age of high river terraces and denudation surfaces in the Bashkirian Pre-Urals (Sakmara-Bel'sk watershed).

2. Materialy VSEGEI, [Material of the All-Union Geological Institute]: new ser., 40, Leningrad, 1960, 188 pp. Contents: Apenko, A. M., G. V. Matveyeva, and M. I. Plotnikova, Discovery of diamonds in Timan and the prospects for diamond exploration; Gnevushev, M. A., V. A. Yefremov, and Ya. R. Pakhlo, Findings of pyrope in the upper course of Dnestr; Umanets, V. N., Ancient oxidized zone on traprock in the eastern part of the Siberian platform; Artsybasheva, T. F., Massive kimberlite in the Alakit River basin (Western Yakutia); Sarsadskikh, N. N., V. S. Rovsha, and V. A. Blagul'kina, Mineral inclusions in pyrope peridotite from kimberlite of the Daldyn-Alakit diamond region; Grum-Grzhimaylo, C. V., and V. S. Rovsha, Coloring in minerals associated with diamond; Tarakhovskiy, A. N., A new variety of melilite-bearing rocks in the White Sea coastal region; Futergendler, S. I., X-ray study of solid inclusions in the Uralian and Yakutian diamonds; Gnevushev, M. A., and Ya. M. Kravtsov, The composition of impurities in Uralian and Yakutian diamonds; Nardov, V. V., Certain morphologic features of diamonds in the light of the mechanism of their growth and dissolution; Titova, V.M., The rhombic pattern of surface fractures in rounded diamond crystals; Gomon, G.O., Absorption and luminescence in diamonds; Gomon, G. O., The results of study of certain physical features of diamond; Razumikhin, N. V., Distribution of diamonds in the longitudinal and transverse sections of a placer; Umanets, V. N., and M. I. Plotnikova, Optimum conditions of slurry washing in prospecting for diamonds; Kravtsov, Ya. M., V. N. Provotorov, and N. N. Sarsadskikh, Determining the specific gravity of minerals in single grains.

3. Same, 44, Leningrad, 1960, 143 pp. Contents: Pisarchik, Ya. K., Relationship between the Verkholensk formation and the underlying section, in the Irkutsk Amphitheatre; Kolyun, M. N., An ancient oxidized zone in the Precambrian of the southern part of the Siberian platform; Librovich, V. L., Origin of Ordovician Red Beds in the Irkutsk Amphitheatre; Malich, N. S., Origin of structures in the basins of Podkamennaya Tungus and Bakhta rivers; Dragunov, V. I., The trans-Siberian transverse disturbance; Polunina, L. A., and M. A. Afanas'yeva, Traprocks in the lower course of the Nizhnyaya Tunguska; Baskov, Ye. A., Some problems in paleohydrogeology of the Yakutian Artesian basin; Razumovskaya, Ye. E., Potassium prospects in the Siberian platfrom; Tikhomirova, N. Ya., Distribution of Titaniferous minerals in Lower and Middle Cambrian deposits of the Irkutsk Amphitheatre; Baskov, Ye. A., and A. A. Roznikov, Ore showings in Cambrian deposits of the Aldan River valley.

4. Materialy Karpato-Balkanskoy assotsiatsii. [Material of the Carpatho-Balkan Association]: No. 2, Kiev, 1960, 148 pp. Contents: Ladyzhenskiy, N. R., Oil and gas in Soviet Carpathians; Porfir'yev, V. B., New ideas in the field of petroleum geology; Sadetski-Kardosh, E., The problem of volcanic Carpathians in the light of a new classification of extrusive rocks; Dzhyushke, D., Evolution of volcanism in the Baya-Mare area; Savul, M., and A. Movilyanu, Manganese, copper, zinc, and lead — dispersed elements in crystalline schist of the Eastern Carpathians; Savul, M., and V. Yanovich, The chemistry of limestones and dolomites in the Eastern Carpathians; Islavskiy, Ya., and I. Chilik, Metallogenic development of the Eastern Carpathians; Zielinski, I. I., Problem poszukiwań faldow wglebnych w rejonie na poludnie od Przemysia.

5. Materialy po geologii i poleznym iskopayemym Yakutskoy ASSR. [Material on the Geology and Industrial Minerals of the Yakutian ASSR]: 4, Yakutsk, 1961, 104 pp. Contents: Shtech, G. I., Deep-seated tectonics of the Vilyuy trough; Levina, A. P., Geomorphology of the Malo-Botuobiya diamond area; Mitt, K. L., Polar land-creep colluvial deposits in the Anabar-Olenek watershed Tundra; Blishovskiy, V. Z., and Yudovich, Ya. E., Origin of amphibolite in the central part of the Tas-Khayakhtakh range; Fatkulin, A. K., A brief mineralogic description of diamond-bearing deposits in the Lower Liassic Irelyakh facies, in the "Mir" vent area; Popov, L. N., Specific features of Upper Triassic and Jurassic deposition in the

Tobychan River basin; Musalitin, L. A., Identification of the Bylykat, Sobopol, and Khaldan formations in Upper Paleozoic section of the Sobopol River basin; Leipzig, A. V., K. F. Klyzhko, and M. P. Khobat, Stratigraphy of Lower Jurassic deposits in the western Upper Yana region; Gornshteyn, D. K., and Yu. S. Nakhabtsev, The age of the sub-red bed formation; Nakhabtsev, Yu. S., Stratigraphic position of the Tolbinsk formation in Lower Paleozoic section; Popov, L. N., Relationship of the two granite varieties in the Chimalgin Massif.

6. Prikladnaya geofizika. [Applied Geophysics]: 4, Moscow, 1960, 204 pp. Partial contents: Blikhin, P. A., Yu. N. Godin, S. S. Yefimkina, and T. I. Shurshayeva, The search for reef massifs; Buryakovskiy, L. A., Determining the clay content and permeability in reservoirs, by their natural radioactivity; Eydman, I. E., and S. Finkelstein, Determining the reservoir properties of carbonate rocks by geophysical methods.

7. Razvedochanaya i promyslovaya geofizika. [Exploration and Oil Field Geophysics]: 38, Moscow, 1960, 115 pp. Partial contents: Zimelson, I. O., Geologic interpretation of local gravity anomalies in the Apsheron Province and adjacent areas of the Caspian coast; Shvank, O. A., Determining the nature of a fault from gravity data; Borodulin, M. I., and S. L. Sheinkman, A method of studying the elastic properties of rocks; Popov, V. K., and V. M. Nemtse-Petrovskiy, Lithologic factor in determining gas saturation of rocks from oil field geophysical data.

8. Trudy VNIGNI. [Works of the All-Union Geologic Exploration Institute for Petroleum Industry]: 29, Leningrad, 1961, 175 pp. Contents: Sazonov, N. T., A unified stratigraphic scheme for Jurassic deposits in the Russian platform (project); Krymgolts, G. Ya., Correlation of Jurassic deposits in the North Caucasus and Russian platform; Mikhaylov, N. P., A zonal differentiation of the lower Volgian stage and its correlation with Bononian and Portlandian of Northwestern Europe; Ayzenstadt, Ye. K., Stratigraphy of Lower and Middle Jurassic deposits in the South Emba oil region; Ivanov, A. N., The basis for stratigraphic differentiations of Jurassic and Cretaceous deposits in Saratovskaya oblast (the Saratov Volga region and the Northwestern part of the North Caspian depression); Malyutina, Z. A., Middle Jurassic deposits of the Orsk Urals; Mityanina, I. V., Stratigraphic differentiation of Jurassic deposits in Belorussia; Grigelis, A. A., Stratigraphic column of Jurassic deposits in the South Baltic region; Yamnichenko, I. M., Stratigraphy of Jurassic deposits on the northwestern margins of the Donbas and Dnepr-Donets trough, in the light of the most recent data; Makridin, V. P., Ye. Ye. Migacheva, and V. P. Strelin, Some controversial points in stratigraphy; Blank, M. I., Jurassic deposits in the eastern part of the Dnepr-Donets trough and the northwestern margin of the Donets ridge; Kanskiy, N. Ye., The value of lithologic and mineral correlatives in the stratigraphy of the Donets Jurassic; Shaykin, I. M., Electric logging in the study and differentiation of Mesozoic sediments in the Dnepr-Donets trough; Dobrynina, V. Ya., Jurassic deposits in the southwestern part of the Russian platfrom and the Pre-Carpathian marginal trough; Anastas'yeva, O. M., O. S. Vyalov, and Ya. M. Sandler, Stratigraphy of Jurassic deposits in the southwestern margin of the Russian platform, and Pre-Carpathian trough; Dibner, V. D., Stratigraphy of Jurassic deposits in Franz-Josef Land; Makridin, V. P., Stratigraphic value of brachiopods from Jurassic deposits in the Russian platform.

9. Trudy Instituta geologii Akad. Nauk Turkm. SSR. [Works of the Geological Institute, Academy of Sciences, Turkmenian SSR]: vol. 3, Ashkhabad, 1960, 305 pp. Contents: Dmitriyev, A. V., Oysters from the Suzak beds of the Manysh syncline; Dmitriyev, A. V., Paleogene oysters in Badkhyz; Krivenkov, A. M., Microfauna in aeolian sands of the Karabogaz region; Amurskiy, G. I., Some problems in the structure of the Karakum formation; Shumakov, Yu. V., The structure of upper quaternary and present deltas of the Amu Dar'ya and the rhythm in delta making; Tiunov, K. V., Quaternary deposits in the Bol'shoy Balakhan and adjacent areas; Valbe, S. P., Yu. G. Kir'yanov, and L. N. Smirnov, Tectonics of the eastern Kopet-Dag foothills and their oil and gas prospects; Ayzberg, R. Ye., Correlation of Upper Jurassic and Lower Cretaceous deposits in the Kelif Uzboy and southwestern prongs of the Hissar range; Sabbatovskiy, G. K., The value of K. P. Kalitskiy's work in the knowledge of the geology of Turkmenian oil fields; Khanov, S., Certain regularities in the distribution of oil and ozokerite in Cheleken Peninsula; Badalov, S. T., Mineral, geochemical and genetic features of the Kugitant Tau range ore deposits; Kuliyev, A., The effect of lateral rocks on the localization of ores in the Kugitang deposits; Krivenkov, A. M., Sand massifs of the Karabogaz region; Kaldarov, M. K., Ground waters in central Transunguz region; Mal'tsev, L. M.,

Formation waters of Pliocene deposits in the Nebitdag fold.

10. Trudy kuybyshevskogo nauchno-issledovatel'skogo instituta neftyanov promyshlennosti. [Works of the Kuybyshev Institute of Petroleum Industry]: 1, Kuybyshev, 1960, 376 pp. Contents: Lobov, V. A., Devonian and Carboniferous gas prospects in the Kuybyshevskaya and Orenburgskaya oblasts; Yegorova, L. Z., Composition of crystalline basement rocks and ancient barren sequences in the Kuybyshev Transvolga region and adjacent areas of the Orenburgskaya Oblast; Yagofarov, E. Kh., Clay minerals in the terrigenous Lower Carboniferous section of northeastern Tataria; Prolove, Ye. K., Petrography of Lower Permian deposits in the Kuybyshev Volga region; Kondulukova, V. V., Differentiation of the Vereya unit, by Foraminifera, in the Kuybyshevskaya and Orenburgskaya oblasts; Kondulukova, V. V., Stratigraphic differentiation of the carbonate interval in the Tournaisian of the Kama-Kinel trough; Rybakov, F. F., Stratigraphy, facies, and paleogeography of Permian deposits in the Kuybyshevskaya and Orenburgskaya oblasts, with reference to the three subdivisions of the Permian; Alekseyev, G. I., Geologic structure of the Buzuluk stratigraphic test area; Lobova, G. V., Some new species of ostracods from the Devonian of the Kuybyshevskaya and Orenburgskaya oblasts; Palant, I. B., New species of ostracods from the Malinovsk beds, Kinel-Cherkassy area, Kuybyshevskaya oblast; Semenova, Ye. G., New species of genus Plicochonetes occurring in the Vereya unit, Kuybyshevskaya and Orenburgskaya oblasts; Alekseyava, G. E., New species of fulsulinids from Upper Carboniferous deposits of the Kuybyshevskaya oblast; Alekseyeva, G E., Stratigraphic significance of Quasifusulina longissima (Moell.) var. elongata Schyk.; Weinbaum, S. Ya., Geochemical facies of the Kuybyshevskaya oblast Paleozoic, in connection with the formation of oil; Weinbaum, S. Ya., Reducing capacity as a criterion of epigenetic changes in rocks; Weinbaum, S. Ya., and V. M. Il'inskaya, Oxidation-reduction activity of Upper Devonian rocks in the Kuybyshevskaya oblast; Zeidelson, M. I., and Chistovskiy, A. I., The gas component of formation waters in the Paleozoic of the Kuybyshev Volga petroleum region, in connection with the origin of oil and gas fields; Zeidelson, M. I., Hydogeology of horizon B_2 in the Pokrovsk oil field, in connection with the origin of oil fields; Kozin, A. N., The role of hydrochemical indexes in evaluating oil prospects under platform conditions, in the Kuybyshev Volga region; Kozin, A. N., Changes in the mineralization and composition of formation waters in productive horizons, in the exploitation of the Samarskaya Luka oil fields; Kozin, A. N., The content of sulfate ions and hydrogen sulfide as a function of the calcium content in formation waters of the Kuybyshev Volga region oil fields; Lobov, V. A., Geothermal conditions of the Middle Volga region; Barkhatova, Z. S., and S. B. Pavel'yev, Geologic effectivness of the d^2Ga/dz^2 maps; Yelanskiy, L. N., On the study of physical properties of rocks from the Kuybyshev Transvolga region; Yelanskiy, L. N., Surface structure of Precambrian basement on the southeast margin of the Russian platform; Pavel'yev, S. V., Non-harmonic periodic functions in seismic exploration; Chalikova, Ye. K., Seismic tracing of thick Lower Carboniferous sections; Boyarov, A. T., Rock resistivity as a function of the concentration of saturating solutions.

11. Trudy Laboratorii vulkanologii Akad. Nauk SSSR. [Works of the Volcanology Laboratory, Academy of Sciences, USSR]: 18, Moscow, 1960, 142 pp. Contents: Bogoyavlenskaya, G. Ye., Volcano Bezymyannyy in Kamchatka and its agglomerate flow; Svyatolovskiy, A. Ye., Volcano Ichinsk in the Sredinnyy Kamchatka range (outline of structure); Marenina, T. Yu., Volcano Opala in Kamchatka; Tikhonov, V. I., and V. A. Kitay, Certain regularities in the geologic structure of the Shapochka volcanic cone in Kamchatka; Ehrlich, E. N., The most recent volcanism in the Tikhaya River basin and Anaun volcano, Kamchatka; Sirin, A. N., Geomorphology and the most recent tectonics in the Paratun Valley, Kamchatka; Lebedinskiy, V. I., The Datum group of Quaternary volcanoes, China; Naboko, S. I., and V. G. Sil'nichenko, The Gauss volcano in Antarctica; Maleyev, Ye. F., The Kuchava-Bystritsa group of volcanoes in Transcarpathia; Piotrovskaya, T. Yu., Quaternary volcanism in the Vygorlyat-Gutin volcanic ridge (Transcarpathia); Aver'yev, V. V., Dynamic features of thermal wells; Naboko, S. I., and V. G. Sil'nichenko, Metamorphism of interacting hydrothermal solutions and volcanic rocks; Ovchinnikov, A. M., Thermal springs in Bulgaria; Naboko, S. I., and V. G. Sil'nichenko, The role of carbon dioxide in Post-Volcanic processes.

12. Trudy Laboratorii gidrogeologii Akad. Nauk SSSR. [Works of the Hydrogeology Laboratory, Academy of Sciences, USSR]: vol. 30, Moscow, 1960, 119 pp. Contents: Balashov, L. S., The two genetic classes of saline waters in sedimentary deposits; Bogomolov, G. V., Ground water as an

exploration criterion and a possible source of rare elements; Makarenko, F. A., The source and magnitude of salt accumulation in Uzboy; Tageyeva, N. V., and M. M. Tikhomirova, Determining the exchange cations in Caspian sediments; Kolodyazhnaya, A. A., Some data on the source of CO_2 in Karst limestones; Voznesenskaya, Ye. F., Ground waters in the Bol'shoy and Malyy Kushums basin; Tetsman, G. N., Fedorova, T. K., and A. S. Dubil'yer, Hydrogeologic differentiation in the southeastern part of the Russian platform; Nikolayev, V. M., Ground water in Maykopian deposits of the Terek-Sunzha oil province; Pokrovskiy, V. A., Thermal waters in the European USSR; Dzhibuti, S. S., A few data on geothermy of the West Turkmenian artesian basin; Titova, Ye. A., Thermal conditions of the Sochi-Matsestin artesian basin.

13. Trudy Sverdlovskogo Gornogo Instituta. [Works of the Sverdlovsk Mining Institute]: 37, Moscow, 1960, 235 pp. Contents: Kutyukhin, P. I., A. P. Nasedkin, and P. S. Pryamonosov, Geology of the eastern greenstone belt in the Kirovgrad area and its ore prospects; Podsosova, L. L., A study of accessory minerals in rocks of the eastern greenstone belt, Kirovgrad area; Malakhov, A. A., and D. I. Bulatov, Composition of the Baykal carbonate iron ores; Chernousov, Ya. M., The quality of Mesozoic coals from the east slope of the Middle and Northern Urals; Knyazev, V. A., Correlation of coal beds in the Bogoslov and Veselovsk deposits, by spectrum analysis; Trifonov, V. P., Efficient classification of placers; Shcheglova-Borodina, O. N., A few data on the stratigraphy of Upper Cretaceous and Paleogene deposits in the Turgay plateau; Sapel'nikov, V. P., New pentameracea from silurian deposits of the Severoural'sk district, Sverdlovskaya oblast; Loburtsev, I. S., Origin of the Sverdlovsk group of lakes; Shabalina, N. S., Hydrogeologic conditions of manganese deposits in Northern Urals; Valiullina, R. T., Stratigraphy of the Omsk syncline; Vertushkov, G. N., Alpine type veins; Chesnokov, B. V., Comparative description of the physical properties of crystalline and metamictic pyrochlores from Vishnevyye Mountains; Pryamonosov, P. S., New findings of amphibole-asbestos in the Kirovgrad area; Isakov, M. G., Amazonite from Vishnevyye Mountains; Svyazhin, N. V., Two zeolites from Mochalin Log (in the South Terminal of Vishnevyye Mountains alkalic massif).

14. Trudy Sibirskogo nauchno-issledovatel'skogo institute geologii, geofiziki i mineral'nogo syr'ya M-va geologii i okhrany nedr SSSR. [Works of Siberian Institute of Geology, Geophysics, and Mineral Raw Material, Ministry of Geology and Mineral Conservation, USSR]: 13, Moscow, 1960, 152 pp. Contents: Vasil'kovskiy, N. P., The theory of geosynclines in the light of modern geology; Arustamov, A. A., The initial or early metamorphism of sedimentary rocks; Predtechenskiy, A. A., An ancient uplift in southern Siberia (in connection with the "ancient crown of Asia"); Vasil'kovskiy, N. P., Geologic significance of changes in level of the world ocean; Mikutskiy, S. P., Stratigraphy of Pre-Upper Paleozoic deposits in the Yenisey portion of the Siberian platform; Sennikov, V. M., Stratigraphy of Devonian deposits and Upper Devonian volcanism in the Uymen-Lebed synclinorium (Gornyy Altay); Belousov, A. F., and V. M. Sennikov, The Cambrian in northeastern Altay; Kutukov, A. V., The formation conditions of the Balakhon series in the Zalomnensk depression, Kuzbas, in connection with the search for oil and gas.

15. Trudy Tadzhikskogo universiteta. [Works of the Tadzhik University]: vol. 28, 1, Stalinabad, 1960, 155 pp. Contents: Yusupova, S. M., Mineralogic and petrographic characteristics of the Khangon Gorge clays; Shestakov, V. A., Specifications for coking-coals slurry from their petrographic composition; Proskurko, A. I., Geology of intrusions in the Transition Province between the Rushansk and North Alichur (Bazardarin) ranges and the central and southeastern Pamirs; Khasanov, A. Kh., Origin of red granites in connection with postmagmatic processes in the Hissar plutonic body; Chediya, O. K., and V. A. Vasil'yev, The nature and age of ancient glaciation on the north slope of the Peter I Range; Poletayev, I. K., Hydrogeologic conditions and the effect of the irrigation network and areas on the water table in the Ak-Gazinsk plateau; Chediya, O. K., The most recent volcanism in the Iman River basin (Middle Sikhote-Alin).

16. Trudy Tsentral'nogo nauchno-issledovatel'skogo gornorazvedochnogo instituta (TsNIGRI). [Works of the Central Mining-Exploration Institute]: 39, Moscow, 1960, 78 pp. Partial contents: Fer'yanchich, F. A., Working out the method of mass determination of small amounts of niobium, tantalum, and rare earths, in large samples; Kovaleva, O. I., Geology of the Tal'mak-Kherpuchi watershed and the relationship between extrusive rocks and gold mineralization.

17. Uchenyye Zapiski Azerbaydzhanskogo

versiteta. [Academic reports of erbaydzhanian University, Geol. - ogr. Series]: No. 4, Baku, 1960, 100 _ Contents: Mamedov, Sh. N., G. G. mikyan, and B. A. Osipova, Tectonics Upper Cretaceous deposits in the south-stern part of the Kirovabad petroleum ovince, from seismic data; Suleymanov, M., Hydrogeology of Mugan steppe; yev, A. G., and V. P. Akayeva, Litho-gy of Azerbaydzhanian molasse; hmedbeyli, F. S., Mesozoic outcrops the south foothill zone of the Greater Caucasus; Museibov, M. A., Tectonic plan of the Kura-Iora watershed, as reflected in present relief; Mamedov, A. V., and Kh. S. Dzabarova, Stratigraphy of Lower and Middle Sarmatian deposits in the Molladag area (Kura-Iora watershed), from fauna and spore-pollen analysis; Akhmedov, G. A., M. M. Zaynalov, R. G. Sultanov, and E. A. Tagiyev, Correlation of productive sections in Apsheron and southeastern Kobystan; Bektashi, S. A., Fracturing in the contact metasomatic belt in the southwest of the Mergi-Ordubad batholith.

CHRONICLE

THE SEARCH FOR THE TUNGUSKA METEORITE[1]

An unusual natural phenomenon, the fall of the Tunguska meteorite, was witnessed over 50 years ago (June 30, 1908) in the Podkamennaya Tunguska area. A study of that area was not undertaken until 1927, nineteen years later, under conditions different from those of 1908. L.A. Kulik observed a mass fall of timber, within a radius of over 10 km, but no tangible evidence of the meteorite. Subsequent search by other students has also been fruitless; no evidence of the meteorite, either on the surface or at depth, has been uncovered.

There is indirect evidence, such as the testimony of eyewirnesses who heard a mighty explosion, also such facts as the radial fall of timber, radiation burns on trees, etc., which supplied material for the more or less logical hypotheses on the nature of this hitherto unexplained phenomenon (for more details, see V.G. Fesenko and Ye.L. Krinov, "New Information on the Tunguska Meteorite", Vestnik Akad. Nauk SSSR, no. 12, 1960).

Because of its very mystery, the so-called fall of the Tunguska meteorite continues to intrigue scientists in various fields. Among them was the late Professor of Moscow Institute of Forestry Nikolay Sergeyevich Vetchinkin (who died in August of 1960) sent to this magazine, shortly before his death, two articles: 1) "Search For the Tunguska Meteorite", and 2) "The Three Explosions Caused by the Fall of the Tunguska Meteorite".

As a token of esteem to his memory, the editors deem it pertinent to present a summary of N.S. Vetchinkin's views. In his detailed analysis of what is known of the meteorite's fall and of the present conditions of the area, he concludes that the meteorite's velocity at the instant of impact was not over 3.5 km/sec. Consequently, it could not have been vaporized completely, as is believed by the members of the Committee on Meteorites, on the basis of the 1958 study.

N.S. Vetchinkin believed that some portion of the Tunguska meteorite had dug in to a certain depth. According to him, this hypothesis explains satisfactorily the explosions he describes describes in his second article. He believes that magnetometric and gravimetric studies should be carried out from a helicopter. In analogy with the geophysical study of the Arizona meteorite crater, such an experiment will provide a reliable check of the hypothesis of a buried portion of the Tunguska meteorite.

THE ACADEMICIAN F. YU. LOEWINSON-LESSING MEMORIAL[2]

The hundredth birthday anniversary of Academician Franz Yul'yevich Loewinson-Lessing, an outstanding Soviet petrographer and scientist, was marked by a symposium on the Problem of Magma and the Origin of Extrusive Rocks, held in Moscow, March 15-17, 1961.

Participating were the Section of Geologic and Geographic Sciences, Academy of Sciences, U.S.S.R.; Institute of the Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, together with the Volcanology Laboratory, Academy of Sciences U.S.S.R.; Geology Department of the M.V. Lomonosov Moscow University; the S. Ordzhonikidze Moscow Geologic Exploration Institute; the Chair of Petrography at the M.I. Kalinin Institute of Nonferrous Metals and Gold; and the Moscow Society of Nature Students.

The symposium aroused the great interest of many scientific workers of Moscow and other

[1]Poiskakh Tungusskogo meteorita, p. 127.

[2]Pamyati akademika F.Yu. Levinson-Lessinga, pp. 127-128.

ies, who attended the meetings. The follow-; papers were read:

1. Ye.K. Ustiyev: "Academician F. Yu. ewinson-Lessing and Modern Petrography".

2. A.S. Ginzburg: "Academician F. Yu. ewinson-Lessing, One of the Founders of ysicochemical and Experimental Petro-aphy".

3. S.I. Naboko: "The Value of Works of Yu. Loewinson-Lessing in the Organization d Development of Volcanologic Studies".

4. V.I. Vlodavets: "The Problem of agma".

5. V.P. Petrov: "Importance of Magmatic fferentiation In the Formation of Igneous cks".

6. Professor Ye.A. Kuznetsov: "New Con-butions to Our Knowledge and Concepts of oblems Dealt with In Loewinson-Lessing's ticles, 'The Problems of Magma'."

7. V.V. Shcherbina: "Acidity of Magmatic elts in the Light of Hydrogen-Free Acids".

8. N.I. Khitrov: "Relationship Between ater and FeO/Fe_2O_3 In a Basic Melt".

9. N.P. Semenenko, of the Ukrainian S.R. Academy of Sciences: "Petrochemi-ry, A Basis For Classification of Igneous cks".

10. G.D. Afanas'yev, Corresponding ember of the U.S.S.R. Academy of Sci-ces: "On the Problem of Granite".

11. Yu.A. Kuznetsov, Corresponding ember of the U.S.S.R. Academy of Sci-ces: "Types of Igneous Rock Associations volving Granitic Rocks, and the Origin of anite and Granitic Magmas".

12. G.V. Pinus: "Origin of Magma Form-g Gabbro-Plagiogranite Rocks (in Tuva)".

13. O.A. Vorob'yeva: "The Problem of kaline Igneous Activity".

14. V.I. Gerasimovskiy: "Geochemical Factors in the Origin of Nepheline Intrusions in the Lovozero Massif".

15. R.M. Yashina: "Magmatic Replacement of Marble in Alkalic Petrogenesis of Southeastern Tuva".

16. A.P. Lebedev: "Genetic Types of Titaniferous Igneous Complexes".

17. G.S. Dzotsenidze, of the Georgian S.S.S.R. Academy of Sciences: "F. Yu. Loewinson-Lessing And the Problem of Caucasian Diabases".

18. M.A. Kashkay, of the Azerbaydzhanian S.S.R. Academy of Sciences: "Spherulites and Nodules in Rocks, Minerals, and Ores".

19. G.P. Bogdasaryan, and K.G. Shirinyam "Magma and the Origin of Extrusive Rocks in Deep-Seated and Extrusive Igneous Activity in Armenia.

20. Ye.K. Ustiyev: "The Okhotsk Volcanic Belt and the Problems of Volcano-Plutonic Formations".

21. Yu.M. Scheinmann: "Relationship Between Major Structures and the Composition of Original Magma".

22. M.V. Gzovskiy: "Tectono-Physical Characteristics of the Genesis of Various Magmas".

Short addresses were given also by Academician D.V. Nalivkin, V.S. Koptev-Dvornikov, P.N. Kropotkin, N.A. Sirin, V.A. Zharikov, V.I. Lebedinskiy, A.I. Strygin, and others.

The Symposium papers will be published in a special issue.

Scientific meetings dedicated to the memory of the scientist were also held in Leningrad, Kiev, Baku, and other cities.

The Presidium of the Academy of Sciences, U.S.S.R. has resolved to name the Kamchatka Volcanologic Station after F. Yu. Loewinson-Lessing.